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FINAL REPORT

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"EFFECTS OF MOSQUITO CONTROL WATER MANAGEMENT ON SOIL CHEMISTRY, HYDROLOGY, AND FISH/CRUSTACEAN MICROHABITAT ASSOCIATIONS ON UPPER MARSH FLATS OF RIM-MANAGED IMPOUNDMENTS AND TIDAL MARSHES"

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EXECUTIVE SUMMARY

SULFIDE DYNAMICS. The measurement of pore and surface water sulfide dynamics in artificial ditches and a natural tidal creek demonstrated similar dynamics. That being an overall trend of increasing sulfide concentrations during the summer, and sharp peaks in the late fall-early winter coinciding with maximum litter inputs. However, impoundment perimeter ditches showed higher sulfide concentrations as compared to tidal creeks. These increased levels are attributed to generally restricted water movement and higher rates of organic deposition there.

In general, water column sulfide levels were not shown to be lethal to aquatic organisms. However, in the summer high sulfide concentrations in bottom ditch waters may be critical to benthic invertebrates. Impoundment management efforts which minimize vegetation mortality and limit the buildup of organic material is encouraged to maintain water quality conducive to marine organisms.

SHEEPSHEAD MINNOW AND FIDDLER CRAB POPULATION DYNAMICS.

The Cyprinodon variegatus (sheepshead minnow) behavioral observation study demonstrated that males are territorial during reproductive periods. In shallow water (<30 cm.), they will defend a territory of approx. 0.5 m. which is the location where mating occurs. Summer marsh flooding as part of a Rotational Impoundment Management (RIM) plan allows Cyprinodon breeding on the marsh surface for 3-4 months longer than in a tidal marsh, resulting in an increased Cyprinodon population size under RIM management.

Published work shows that Uca (fiddler crab) populations are important components of the marsh system contributing to the breakdown of plant material and nutrient cycling. This study demonstrated that high water levels can affect Uca distribution patterns at all sites. RIM management caused a major impact on burrow density and distribution with a complete loss of burrows at lower elevations. The fall sea level rise, beginning in September and continuing until November, lowered Uca numbers, especially at lower marsh elevations. This effect continued the loss of lower elevation burrows at Impoundment 12 as well as complete loss at the created marsh (Grand Harbor), and lowered densities at the other sites. At the RIM-managed and created marsh sites consistently low Uca densities occurred year-round, perhaps coincidental with the sparce vegetation which occurs there. At the other study sites, which are moderate to densely vegetated, Uca were present year-round.

SUMMARY

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TASK 1. COMPARE UPPER MARSH SOIL CHEMISTRY AND COMPOSITION BETWEEN RIM-MANAGED IMPOUNDMENTS AND TIDAL CREEKS.

An examination of the pore and surface water sulfide dynamics in several Indian River lagoon salt marshes indicates that sulfide dynamics of impoundment perimeter ditches appear similar to those of natural tidal creeks. The general trend observed was for increasing sulfide concentrations in the summer with peaks in the late-fall, early winter period when litter input to the sediments peaks. On average, the natural creek had the lowest sulfide concentrations and the managed impoundment perimeter ditch had the highest. These elevated sulfide levels in perimeter ditches are attributed to the resticted water movement and higher rates of organic deposition there.

Relatively low sulfide concentrations were measured in the water column. Thus, aquatic organisms encounter toxic levels only in the ditch bottom during the summer months. Most bottom-inhabiting fish are usually able to avoid such stress through behavioral or physiological adaptations. However, the summer may be a critical time of the year in the population cycles of benthic and epibenthic invertebrates that inhabit the ditch bottoms.

Perimeter ditch water quality, especially during the summer months, may be enhanced by periodically exporting organic matter from the ditch rather than letting it accumulate there. Possible means to accomplish this include improving impoundment-lagoon connection wherever possible as well as periodic draining and re-flooding of the impoundment during the summer. Also, preventing large scale vegetation kills is important to preserve water quality since decaying vegetation is the major organic input. Delaying the seasonal culvert opening until lagoon water levels rise in the fall is important to prevent massive fish kills that have been associated with high sulfide and low dissolved oxygen levels in the perimeter ditches.

The comparative study of soil composition among managed impoundment, breached impoundment and an unimpounded marsh is not complete pending final collection of samples this month and their lab analysis. Preliminary data comparisons indicate that the soils of breached impoundments and unmanaged marsh are more similar to each other than to those of the managed impoundment studied. Complete analysis will be presented in an upcoming progress report.

MANAGEMENT CONSIDERATIONS.

1) Delay fall impoundment opening until lagoonal water levels meet or exceed those within the impoundment to minimize organism entry into impoundment waters where poor water quality (high sulfides and low dissolved oxygen levels) may negatively affect their survival.

2) Minimizing vegetation kill due to impoundment flooding is important to limit the buildup of organic material into the system.

3) Draining and reflooding impoundments at regular intervals during the summer months as a means to export organics trapped in the perimeter ditch could ameliorate water quality degradation.

4) Increase the amount of organic matter exported to the lagoon by increasing the number and size of culverts connecting the marsh with the lagoon.

TASK 2. COMPARE SHEEPSHEAD MINNOW AND FIDDLER CRAB POPULATION DYNAMICS, FEEDING AND REPRODUCTIVE BEHAVIOR BETWEEN DIFFERENT MARSH MICROHABITATS UNDER DIFFERENT WATER REGIMES.

Previous CZM funded impoundment management studies have documented that along with Gambusia holbrokii (mosquitofish), and Poecilia latipinna (sailfin molly), Cyprinodon variegatus (sheepshead minnow) is the dominant marsh resident fish in impounded marsh systems. This study, which observed Cyprinodon behavior in impounded and tidal marsh locations, documented the territoriality of Cyprinodon males during their reproductive periods. During these reproductive times, males defend a territory of approx. 0.5 m. in diameter in shallow water (<30 cm.). It is within these defended territories that mating occurs.

Summer impoundment flooding under Rotational Impoundment Management provides a longer marsh surface breeding period than in a tidal marsh. In addition, all Cyprinodon observation sites developed an algal mat while flooded, a primary food source for Cyprinodon. Therefore, this extended flooding period allows for an increased Cyprinodon population to develop under RIM conditions.

Previously published studies of Uca (fiddler crab) populations in a variety of marsh habitats documented that Uca are important marsh components. They provide a bio-turbation function by contributing to the breakdown of plant material as well as nutrient cycling.

This study demonstrated that high water levels negatively affect Uca distribution. High water levels associated with RIM summer flooding showed a complete loss of burrows at Impoundment 12. Correspondingly, the fall sea level rise, beginning in September and continuing until November, lowered Uca numbers along the transects studied, in particular, at lower marsh elevations.

At the RIM-managed (Impoundment #12) and created marsh site (Grand Harbor), where marsh vegetation was sparce, consistently low Uca densities occurred year-round. At the other moderate to densely vegetated study sites, Uca were present year-round.

MANAGEMENT RECOMMENDATIONS.

1) Decrease the length of time that the marsh surface is closed and flooded by delaying flooding.

2) Increase the amount of non-flooded marsh surface by reducing flooding elevations.

TASK 3. PROVIDE SCIENTIFIC REPORTS AND PRESENTATIONS AND PUBLICATIONS FROM THE INFORMATION GENERATED FROM TASKS 1 & 2.

Listed below is: 1) a chronology of presentations made during the past year which drew on CZM sponsored research and 2) a list of 1989-90 publications from CZM sponsored work.

1) PRESENTATIONS DRAWING ON CZM SPONSORED WORK.

NOVEMBER 1989:

FLORIDA ANTI-MOSQUITO ASSOCIATION FALL MEETING (Punta Gorda). Doug Carlson's presentation updating activities of the Subcommittee on Managed Marshes (SOMM) acknowledged the importance of CZM sponsored research.

REGIONAL COASTAL MANAGEMENT SEMINAR (Vero Beach). At this University of Fla., Institute of Food and Agricultural Sciences seminar, Peter O'Bryan presented: "Mosquito control: function and management of impoundment areas and control methods used". CZM sponsored research was the focus for the impoundment management portion of this seminar.

DECEMBER 1989:

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT (Palatka). At John Minton's (Governing Board Chairman) invitation, Doug Carlson summarized salt marsh management along the IR lagoon to the the SJRWMD Governing Board. The highlights and management implications of CZM sponsored work was the focus of this presentation. SJRWMD began taking an increasingly important role in salt marsh management along the IR lagoon through their administration of the SWIM (Surface Water Improvement and Management) program.

FEBRUARY 1990:

FLORIDA ANTI-MOSQUITO ASSOCIATION SHORT COURSES (Ocala). Doug Carlson was an instructor in a course "Environmental Issues Affecting Mosquito Control". This presentation covered the political and scientific implications of mosquito control water management stressing CZM sponsored research as the basis for the impoundment management improvements currently used.

APRIL 1990:

AMERICAN MOSQUITO CONTROL ASSOCIATION (Lexington, KY). Doug Carlson made a presentation entitled "Interagency cooperation in developing management plans for Florida's salt marshes".

FLORIDA MOSQUITO CONTROL ASSOCIATION (Ocala). Doug Carlson's presentation was entitled "The SWIM program: cooperation between the St. Johns River WMD, HRS, and the Subcommittee on Managed Marshes in promoting improved salt marsh management".

MAY 1990:

PAN AMERICAN CONGRESS OF TROPICAL MEDICINE (Mexico City, Mexico). Jorge Rey's presentation was entitled: "Manejo del Ambiente para el Control de los Mosquitos Aedes taeniorhynchus and Aedes sollicitans.

SEPTEMBER 1990:

CAYMAN ISLANDS INTERNATIONAL MOSQUITO CONTROL CONFERENCE. At this Grand Cayman conference, Doug Carlson was an invitational speaker, who presented a paper on Rotational Impoundment Management. This conference reviewed the Cayman Islands mosquito control program and made recommendations on directions the program should pursue. Increased emphasis on physical control was one focus of discussion.

NAVIGATING THE NINETYS (FLORIDA COASTAL MANAGEMENT CONFERENCE, Clearwater).

A) At this DNR/DER sponsored conference, Doug Carlson organized and moderated a session entitled: "Current techniques and issues in salt marsh water management". Four presentations summarized the research, management experience and interagency cooperation accumulated over the past decade of salt marsh management for mosquito control and natural resource enhancement. Two presentations directly drawing on CZM sponsored work were:

1) "Rotational Impoundment Management (RIM): implementation and management issues", Peter O'Bryan, Indian River MCD.

2) "St. Lucie Mosquito Control District's environmental enhancement techniques in rotationally managed (RIM) impoundments", James David, St. Lucie Co. MCD.

B) Dr. Grant Gilmore organized and moderated a session entitled: "Habitat management". Two presentations within this session drawing on CZM work were:

1) "What good is a periodically flooded mud flat? Who lives, eats and reproduces in marginal wetlands of Florida?, Dr. Grant Gilmore, HBOI.

2) "Vegetation dynamics in impounded marshes along the Indian River lagoon", Dr. Jorge Rey, FMEL.

OCTOBER 1990:

44TH ANNUAL CONFERENCE OF SOUTHEASTERN ASSOCIATION OF FISH AND WILDLIFE AGENCIES (Richmond, VA). Dr. Grant Gilmore was invited to give a paper entitled; "Annual sea level rise as an effector of high-low marsh trophic interactions in subtropical Florida", which incorporated several years of CZM funded work.

2) PUBLICATIONS DRAWING ON CZM SPONSORED WORK.

Douglas B. Carlson, Peter D. O'Bryan and Jorge R. Rey. 1991. A review of current salt marsh management issues in Florida", Journal of the American Mosquito Control Association, in press.

Peter D. O'Bryan, Douglas B. Carlson and R. Grant Gilmore. 1990. Salt marsh mitigation: an example of the process of balancing mosquito control, natural resource, and development interests. Florida Scientist, Vol. 53, No. 3: 189-203.

Jorge R. Rey et al. 1989. Salt marsh and mangrove forest soils in impounded wetlands, Journal of the Florida Anti-Mosquito Association 60:50-55.

Jorge R. Rey et al. 1990. Effects of re-establishing tidal connections in two impounded subtropical marshes on fishes and physical conditions. Wetlands 10:27-45.

Jorge R. Rey et al. 1990. Vegetation dynamics in impounded marshes along the Indian River Lagoon, Florida, USA. Journal of Environmental Management 14:397-409.

Jorge R. Rey et al. 1990. Above-ground vegetation production in impounded, ditched, and natural Batis-Salicornia marshes along the Indian River Lagoon, Florida, USA. Wetlands 10:1-21.

Jorge R. Rey et al. 1991. Wetland impoundments of east-central Florida. Florida Scientist 54:, in press.

Jorge R. Rey and R.W. Stahl. 1991. Manejo del ambiente para el control de los mosquitos Aedes taeniorhynchus and Aedes sollicitans. Pan American Health Organization, Boletin de la Direccion General de Malariologia y Saneamiento Ambiental, in press.

Impoundment Pore Water Sulfide Dynamics and Soil Chemistry.

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December 12, 1990

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CONTRACT-RELATED ACTIVITIES

PUBLICATIONS

Rey, J. R., et al. 1989. Salt marsh and mangrove forest soils in impounded wetlands. J. Fl. Anti-Mosq Assoc. 60: 50-55.

__________ . 1990. Effects of re-establishing tidal connections in two impounded subtropical marshes on fishes and physical conditions. Wetlands 10: 27-45.

__________ . 1990. Vegetation dynamics in impounded marshes along the Indian River Lagoon, Florida, USA. J. Environmental Management 14: 397-409.

__________ . 1990. Above-ground vegetation production in impounded, ditched, and natural Batis-Salicornia marshes along the Indian River Lagoon, Florida, U.S.A. Wetlands 10: 1-21.

__________. 1991. Wetland impoundments of east-central Florida. Florida Scientist 54:, in press.

__________. 1991. Zooplankton of impounded marshes and shallow areas of a subtropical lagoon. Florida Scientist 54:, in press.

Rey, J. R. and R. W. Stahl. 1991. Manejo del ambiente para el control de los mosquitos Aedes taeniorhynchus and Aedes sollicitans. Pan American Health Organization, Boletin de la Direccion General de Malariologia y Saneamiento Ambiental, in press.

Carlson, D. B., P. D. O'Bryan, and J. R. Rey. 1990. A review of current salt marsh management isuues in Florida. J. Amer. Mosq. Control. Assoc., in press.

PRESENTATIONS (1990).

Manejo del Ambiente para el Control de los Mosquitos Aedes taeniorhynchus and Aedes sollicitans. Pan American Congress of Tropical Medicine, Mexico City.

Vegetation Dynamics in Impounded Marshes along the Indian River Lagoon. Florida Coastal Management Conference. Clearwater, Fl.

GENERAL INTRODUCTION

This report covers two distinct projects: the impoundment pore water sulfide study, and the marsh soils study. The first study has been completed and a full report of the results and conclusions are presented here. Field work for the second project is still under way. We expect to collect the last soil samples this month, which means that laboratory analyses will not be completed until late February. Consequently, analysis of these data will not be finished for at least three more months. Here we present only some summary data to give an indication of the sources of variation that we will be dealing with, and of the general shape of the data set.

PORE WATER SULFIDE DYNAMICS

INTRODUCTION

In salt marshes, a significant proportion of the energy contained in organic matter, particularly that produced underground, is processed through the sulfur cycle (Howarth and Teal 1980, King 1983, Gardner et al. 1988). Energy produced by sulfate reduction is directly utilized by microorganisms responsible for the process, or is stored underground as reduced sulfur compounds, mainly hydrogen sulfide (H_2S), iron monosulfide (FeS), or pyrite (FeS_2) (Howarth et al. 1983). The process of sulfate reduction is also important because some by-products of sulfate oxidation (e.g. H_2S) can be toxic to marsh vegetation (Nickerson and Thibodeau 1985) and to aquatic organisms (Abel et al. 1987), and all generate acidity upon oxidation. H_2S can also act as a strong scavenger of dissolved oxygen. Thus, many aspects of the sulfate reduction process have the potential to produce stressful conditions for the marsh flora and fauna, particularly in areas with reduced water flow such as in isolated marsh depressions or impounded marshes (Gaviria et al. 1986).

Salt marsh impoundments are common in many areas of the world and have been used for a wide variety of purposes including agriculture (Tompkins 1986), aquaculture (Bardach et al. 1972), waterfowl management (Hardin 1987), water storage (Baxter 1977), mosquito control (Provost 1977), and others. Over 16,000 ha of salt marshes and mangrove forests bordering the Indian River Lagoon, in east central Florida, have been impounded for mosquito control. Impounding involves construction of a dike around the marsh with material excavated from the marsh perimeter thus creating a ditch that borders the dike on the inside of the marsh. This allows artificial flooding of the marsh during the mosquito producing season and eliminates mosquito production because the salt marsh mosquitos *Aedes taeniorhynchus* Wied. and *A. sollicitans* Walker will not oviposit upon standing water. Only a few centimeters of water are required to prevent mosquito oviposition.

In this area, impoundments are usually artificially flooded in late spring, and are maintained flooded during the summer. In the past, most agencies attempted to minimize the adverse effect of impounding upon the marsh and lagoon systems by opening the culverts connecting the impounded marsh with the lagoon as soon as potential mosquito production declined, usually in early or mid September. This practice, however, often creates problems because during the flooded period, the water in the perimeter ditches become highly stratified, with an anoxic lower layer with high sulfide concentrations (G. Gilmore and P. Carlson, unpublished data). In early September, water levels in the lagoon are low so when the culverts are opened, water flows out from the impoundment into the lagoon and the oxygenated upper layer in the ditches is drained, leaving only the anoxic high sulfide lower layer. As marsh water levels drop, aquatic organisms have to retreat from the upper marsh into the perimeter ditches, were the interaction of low dissolved oxygen and high sulfide prove lethal to many species (Peterson 1990), and often result in massive fish kills.

A great deal of effort has been devoted during the past years to preventing fish kills when the culverts are opened. Some new techniques such as bottom-water release culverts (which drain the ditches from the bottom) and overpumping lagoon water into the ditches prior to opening (to break up the stratification), have been found to significantly improve conditions in the ditches when the impoundments are drained (Carlson et al. 1989, David and Vessels 1989). These techniques, however, are often expensive and very labor-intensive. An alternative is to delay culvert opening until the water levels in the lagoon rise in late September or early October, and open the culverts at high tide. In this way, lagoon waters will first flow into the impoundment and mix with the impoundment water thus improving overall water quality and breaking up the stratification in the ditches before the marsh drains at low tide.

This study investigates the sulfide dynamics in impoundment perimeter ditches and the surrounding pore waters. Specifically, we compare the sulfide concentrations in a functional managed impoundment with those in an impoundment that remains open all year and those in a nearby tidal creek. We also examine the effects of delayed fall opening of the managed impoundment upon sulfide concentrations in the pore and surface waters.

STUDY SITES

Three sites were selected for this study; two impoundments (IRC #12 and Blue Hole) and a natural tidal creek (Figure 1). IRC #12 is a 128.4 ha impoundment on the barrier island side of the Indian River lagoon at the Indian River-St. Lucie county line. The impoundment is connected to the lagoon via two 76.2 cm diameter culverts with risers, and two 45.7 cm diameter culverts with flapgates. The culverts connecting the marsh with the lagoon were closed on June 8, 1989 and the marsh was flooded for mosquito control by pumping in lagoon water. The culverts were re-opened at high tide on September 22, 1989, at which time lagoon water levels were high enough to flood the marsh. Blue Hole is located approximately 1.5 km south of IRC #12. It covers an area of 743.5 ha, and is connected all year to the lagoon via a 76.2 cm diameter culvert with no control structures, and through a breach on the dike on the northeast side of the impoundment. The tidal creek is located 1.5 km south of Blue Hole. It is approximately 15m wide with a mean depth of approximately 95cm. It runs from a natural marsh into the lagoon, approximately 180m away and has no flow restrictions throughout its length.

METHODS

At each site, two pore water sampling stations were established on the creek or ditch banks, and one in mid-channel. Additional stations were established to sample the water column in the center of the ditches or creek at the three sites.

Samples were collected biweekly at depths of 15, 30, and 45 centimeters below the marsh floor, not more than 1 hour before or after high tide using modified versions of the pore water samplers described by Zimmermann et al. (1978; Figure 2). Additional samples were collected on September 22, 1989 prior to opening the culverts, 2 hours and 8 hours after the culverts were opened, and at high tide the following morning. The samplers were permanently installed at the appropriate depth and were only removed if repairs or replacement became necessary.

The water column samplers were suspended in a float so that samples were always collected 35 cm below the water surface. Equipment and time constraints did not permit more intensive sampling of the water column, therefore we chose the above depth to allow sample collection even when water levels were low, and to reflect the quality of the habitat available for aquatic organisms during low water periods and during the critical fall opening.

Sample Collection.

Samples were removed by pumping in nitrogen gas through the sampler's gas intake valve (Figure 2) to completely purge the system of oxygen. The samples were collected directly into vacuum sealed 50 ml serum bottles that were filled with nitrogen gas. This was done with a plastic tubing and needle arrangement that penetrated the rubber seal without introducing air into the sample bottles. All samplers were purged of accumulated water 12 hours prior to sample collection, and were sealed to the atmosphere afterwards.

After collection, 10 ml of pore water for sulfide analysis were removed from the bottles with 20 ml syringes which contained 10 ml of freshly-prepared SAOB and which were wrapped in aluminum foil and kept in a cooler. After collection, each syringe was again wrapped with aluminum foil and returned to the cooler. Thus, there was no exposure to oxygen and only minimal exposure to light during the sample extraction and fixing process. The water remaining in the serum bottles was used to obtain measurements of dissolved oxygen and temperature (YSI Model 51B meter), pH (Gallenkamp pH Stick), and salinity (AO temperature compensated refractometer).

In the laboratory, sulfide determinations were made not more than three hours after collection using an Orion EA940 Ion Analyzer with a Model 94-16 Silver/Sulfide electrode, a Model 90-02 double junction reference electrode, and an Orion Automatic Temperature Compensator (ATC) probe. Prior to analysis, the system was calibrated using Orion Sulfide Standards. Standards covering the range of concentrations normally encountered in our samples were also run after every 4 samples.

Data Analysis.

All data analyses were performed using SAS (SAS Institute, Cary N.C.) on a Microvax II computer. ANOVAS were performed with the GLM procedure of SAS, and the Waller-Duncan a-posteriori test was used to examine individual differences for significant ANOVA terms. If significant interactions were discovered in multiway and nested ANOVAS, the interacting terms were analyzed separately using one-way analyses.

RESULTS

Pore water temperatures during the study ranged from 16°C in winter to 40°C in summer with dissolved oxygen and pH ranges during the same interval of 0 to 5.8 ppm and 4.5 to 8.6, respectively. Salinity ranged from 26 to 75 ppt. Drought conditions during late spring and summer of 1989, coupled with high evaporation rates, combined to produce the highest salinity values observed during the study. Pore water sulfide concentrations ranged from 0.02 to 1640 μg-at/liter. Mean sulfide concentrations ranged from 0.16μg-at/l at the tidal creek to 436.52μg-at/l at IRC #12 (Table 1).

Site-Station-Depth Effects

There were significant differences between sites in pore water D.O., temperature, salinity, and sulfide (Table 2). Results of Waller Duncan tests indicate that creek pore waters had the lowest temperature and sulfide concentration and the highest D.O., whereas IRC #12 had the highest salinity and sulfide concentrations and Blue Hole the lowest D.O. (Table 2).

Significant differences between stations within sites, and between depths within stations were evident only for salinity and sulfide. Differences in salinity with depth were only significant at Blue Hole, where the salinity increased with depth. Sulfide, however, increased with depth at all three sites (Table 3). At the two impoundments, the mid-channel station had higher sulfide concentrations than the bank stations but the opposite was true at the tidal creek (Table 3).

There were no significant differences in water column D.O., temperature and salinity (Table 4). Water column sulfide was higher at IRC #12, than at Blue Hole and the tidal creek, whereas pH at the tidal creek was lower than at the other two stations (Table 4).

Seasonal Patterns

Seasonal patterns in sulfide concentrations at the creek and ditch bank stations were similar at all sites. There was a trend of increasing sulfide starting in the summer, with sharp peaks in late fall and early winter. Sulfide then decreased steadily, and remained low during late winter and spring except for the 45cm samples at the bank stations which displayed an increasing trend, starting in late spring (Figure 3).

At the mid channel stations, there was no increasing trend during summer, except for the 15cm samples at Blue Hole, which peaked during August and September (Figure 4). At the two impoundments, mid-channel sulfide peaked during November and December, and decreased steadily thereafter, whereas at the tidal creek it peaked sharply during September-October and remained low during the rest of the year (Figure 4).

Water column sulfide was less than 1 μg-at/l throughout the year, except for small peaks at IRC #12 when the culverts were closed in June 1989 (up to 3 μg-at/l), and just before they were opened in September (1 μg-at/l).

Fall Opening.

In the ditch bank stations at IRC #12, sulfide concentrations at all depths increased after the culverts were opened in September 1989. The increase continued through the receding tide and reached near twice the original levels at 15 and 30 cm, with a smaller increase (about 30%) evident at 45 cm (Figure 5). By the first high tide the following day, sulfide levels had again dropped, but were still higher than before culvert opening (Figure 5). At the mid-channel station, the 15cm samples exhibited patterns similar to the above. At 30cm, sulfide concentration decreased after culvert opening whereas at 45cm, sulfide concentration first decreased and then increased so that by the next high tide, levels were higher than before opening (Figure 5). Water column sulfide levels remained low throughout the interval; they dropped slightly with each sample, going from 0.22 μg-at/l before the culverts were opened, to 0.13 μg-at/l the next day.

DISCUSSION

The standing stock of sulfide at a given location is the result of several processes, particularly the rate of sulfate reduction, the rate of sulfide precipitation as metal sulfides, the rate of flushing of sulfide-containing pore waters, and the amount and sulfide concentration of water exchanged with other locations.

Sulfide concentrations at the bank stations were somewhat lower than reported for temperate marshes (Howarth et al. 1983, Carlson and Forrest 1982), but were similar to those reported from creekside stations in Georgia (King et al. 1982) and South Carolina (Gardner et al. 1988). In general, they were higher than those reported by Carlson et al. (1983) for black mangrove (Avicennia germinans) zones in nearby overwash mangrove island sediments (0 - 100 μM), but lower than pore water concentrations found by the same authors in red mangrove (Rhizophora mangle) zones (10 - 1500 μM).

Creek and ditch bank areas such as the ones where our stations are located usually have lower sulfide concentrations than back marsh areas (King et al. 1982, Gardner et al. 1988). Several factors that have been found to produce lower standing stocks of sulfide at creekside than in the back marsh are also probably responsible for the relatively low levels found at our sites: 1) faster drainage of sulfide-containing pore water into the creeks and ditches (Gardner et al. 1988, Agosta 1985); 2) Higher inputs of reactive iron at creekside (King et al. 1982); 3) Higher levels of bioturbation at creekside recycle reactive iron so that iron reduced at depth is brought to the surface and oxidized, and fresh iron oxides are transported downward where they react with sulfides and precipitate as FeS or FeS_2 (Gardner et al. 1985, Gardner 1990). Although many Florida marshes are poor in iron (Hsieh and Yang 1989), high iron content and high rates of sulfide precipitation as FeS have been reported from nearby marshes by Carlson et al. (1983); 4) Portions of the creekside sediments receive greater aeration than upper marsh sediments, particularly when negative pore pressures develop as a result of shifting water levels (Agosta 1985).

Site Comparisons.

The higher sulfide concentrations present at IRC #12 than at the other two sites probably result from a variety of factors: 1) The restricted water flow and exchange with the lagoon reduces the rate of flushing of sulfides (King et al. 1982, Howarth and Giblin 1983) and the input of reactive iron to the sediments (King et al.

1982, Giblin and Howarth 1984). The scant water flow may also increase the rates of sulfate reduction by promoting more reducing conditions in the sediments (Jorgensen 1977). 2) Soils at IRC #12 have a higher organic matter content than Blue Hole (Rey et al., in prep.) and probably than the natural creek. This is a result of widescale vegetation kills at that site in the past (Rey et al. 1990a), and of higher rates of yearly plant litter input caused by localized vegetation kills that often occur during the flooded period in the summer (Rey et al. 1990a). The higher organic matter content will promote higher rates of sulfate reduction (Gardner et al. 1988).

Similar factors may be responsible for sulfide concentration patterns at the mid-channel stations. The reduced water flow in the impoundments limits the amount of sulfide that can be removed from the sediments, particularly during summer, when perimeter ditch stratification is most pronounced. Additionally, litter produced in the impoundments must reach the perimeter ditches and then make its way to one of the culverts (or the breach at Blue Hole) before it is exported to the lagoon. This situation clearly fosters the accumulation of organic matter in ditch bottoms thus promoting sulfate reduction.

Seasonal Patterns.

Previous studies report that salt marsh sulfide concentrations are highest in late summer (Jorgensen 1977, Howarth & Teal 1979, Howarth et al. 1983). This pattern has been attributed to higher reducing activity during those times (Howarth et al. 1983), to higher inputs of organic matter to the sediments due to plant senescence (Howarth and Teal 1979), or death of the benthic fauna due to anoxia (Jorgensen 1977), and to concentration of sulfide as a result of high rates of evapotranspiration in summer (Gardner et al. 1988). Carlson and co-workers, however recorded their lowest sulfide concentrations during the summer and attribute this pattern to the low water levels typical of this area during that season (Carlson et al. 1983).

Although in this area reducing activity is highest during late summer (Lahmann 1988), peak vascular plant detritus input into the sediments in this area does not occur until late fall or early winter (Rey et al. 1990b). Thus, we have a pattern of increasing sulfide concentrations during the summer (with increasing reducing activity and evapotranspiration) and more or less sharp peaks during late fall - early winter which correlate with peak detritus input into the sediments.

The sharp drops in sulfide levels evident at all sites after December correspond with the yearly drop in Lagoon water levels, which increases exposure of the marsh surface and drainage of the pore waters. Because the mid-channel stations are permanently flooded, the seasonal differential in reducing activity and evapotranspiration are probably less pronounced there than at the bank stations, which may explain the lack of a consistent rise in sulfide during the summer at mid-channel.

Fall Opening.

The increase in sulfide concentrations evident at the bank stations of IRC #12 after the culverts were opened in September 1989 are puzzling as one would expect the increased flushing and the replacement of stagnant impoundment water with lagoon waters to cause a decrease in concentration. It is possible that sulfate became limiting during the summer and sulfate reduction rates increased when fresh sulfate was introduced in the incoming lagoon waters, thus causing the observed increase in sulfide stocks. This is not an unreasonable process considering the fact that the impoundment was closed for three months prior to opening, which means that no fresh sulfate was introduced into the system during a period when reducing activity is usually highest. Although sulfate is abundant in sea water and is seldom limiting in marine and estuarine surface waters (Howarth and Teal 1979), pore water sulfate concentrations are often much lower, particularly at depth (Jorgensen 1977). Several studies have demonstrated drops in pore water sulfate levels during periods of low water movement (Jorgensen 1977, Giblin and Howarth 1984); for example, Lee and Kim (1990), working in intertidal sediments in Korea, found that high reductions rates could cause total depletion of sulfate from pore waters.

Alternatively, the rise in sulfide at our stations may be a result of lateral transport of high sulfide pore water from the marsh interior to the ditch and creek banks. Recall that the culverts at IRC #12 where opened at high tide. Two hours later, when the "AFTER" samples were taken, water levels in the lagoon were receding, but because of the restricted nature of the exchange pathways between marsh and lagoon (culverts), levels in the former drop slower than in the latter. As a result, a head differential is established that slopes down towards the perimeter ditch. Such a process is known to force lateral movement of pore water in the direction of decreasing head (Agosta 1985).

Examination of the salinity patterns during the same interval indicate that both of these processes may be at work. Initially, pore water salinity dropped, which indicates that the major water flux was that of the incoming, lower salinity (high sulfate), lagoon water into the sediments. As the tide receded in the lagoon, salinity rose indicating transport of higher salinity water from the marsh interior into the perimeter ditch area, eventually elevating salinity to higher levels than before the culverts were opened. The observation that salinity changes at 45cm lagged behind those at 15 and 30cm suggests slower vertical and horizontal transport at that depth.

The fact that water column sulfide levels remained low throughout the study is partly due to the fact that our samples were not collected at the bottom, where high sulfide concentrations are common in summer. However, we did not observe high sulfide concentrations when the top layer was drained in the fall (the culverts at IRC #12 are not the bottom-release type). This indicates that the incoming lagoon water effectively mixed with that in the ditches lowering sulfide concentrations by dilution and also by oxidation of sulfide in the formerly anoxic layer; the latter is also suggested by a drop in water column pH from 7.2 to 6.8 after the culverts were opened (King et al. 1982).

CONCLUSION

Sulfide dynamics of impoundment perimeter ditches appear to be similar to those of natural tidal creeks. Higher levels of sulfide in ditches than in tidal creeks are promoted by restricted water movement and by higher rates of organic matter input in the former. The water flow bottleneck created by the culverts may foster the lateral transport of pore waters when lagoon water levels are changing and increase the accumulation of organic matter in the ditch bottoms.

The low sulfide levels measured in the water column indicate that aquatic organisms are not likely to encounter toxic levels of this substance in the ditches, except near the bottom in summer. Most bottom-dwelling fishes that inhabit these impoundments during summer have behavioral and/or physiological adaptations that help them survive the summer conditions (Peterson 1990), but that time of year may be critical in the population cycles of benthic and epibenthic invertebrates that inhabit the ditch bottoms. Delayed fall opening of the impoundment culverts effectively prevented entrapment of aquatic organisms in the anoxic, high-sulfide layer of the perimeter ditches after the fall opening of culverts.

Conditions in the perimeter ditches would probably be enhanced by allowing a greater fraction of the organic matter produced in the marsh to be exported to the lagoon instead of accumulating in the ditch bottoms. This could be accomplished by increasing the number and size of culverts connecting the marsh with the lagoon, and also by preventing widescale vegetation damage when the impoundment is flooded in summer. The latter is important because vegetation killed in early summer will be trapped within the impoundment until the culverts are re-opened in the fall and thus has a high probability of being sequestered in the perimeter ditches.

Attention needs to be devoted to the actual rates of sulfate reduction, particularly from late spring to late fall. If the suggestion that sulfate reduction during summer is limited by the availability of substrate is generally true then some schemes to improve impoundment water quality, such as draining and reflooding the impoundments at regular intervals during the summer, may have unexpected results.

SALT MARSH SOILS

INTRODUCTION

A great deal of research undertaken during the past years on the biology of salt marsh impoundments has resulted in valuable information on the fauna, flora, surface and pore water chemistry, and other components of the marsh-impoundment system. Very little attention, however, has been devoted to the soil characteristics of impounded marshes. This neglect parallels the dearth of information on salt marsh soils in general, perhaps because of the limited potential of these areas for agricultural development (Coultas and Calhoun 1976).

Soils can exert a significant influence on many aspects of salt marsh biology such as plant establishment and growth, physical conditions of the water column, productivity, rate and by-products of organic matter decomposition, and many others (see Jenny (1980), Greenland and Hayes (1981), and Scott et al. (1989) for general discussions). Moreover, the soil-inhabiting biota is an important component of the marsh system and has the potential for significant impacts upon the marsh. Sulfur-reducing bacteria, for example, can cause significant changes in the salt marsh environment. Their impact, however, can be minimized by other components of the soil fauna such as bacteria of the genus Beggiatoa that protect against hydrogen sulfide toxicity by oxidizing H_2S to S. The soil fauna and flora also figure prominently in the overall marsh energetics and production dynamics (Odum 1988).

Marsh soils can be extremely variable both between and within marshes, but they usually contain a large proportion of fine sands and clays of marine origin, and are moderately to highly saline. Frequent tidal flooding, and sodium defloculation of sand and silt combine to seal pore spaces and cause most salt marsh soils to be moderately to strongly reducing very near the surface. They can be neutral, acid, or basic depending upon the parent material, the soil fauna, and the marsh hydroperiod.

Salt marsh soils are often deficient in nutrients needed for plant growth, particularly phosphorus and nitrogen (Gallagher 1975, Boto and Wellington 1984). Some anaerobic organisms (e.g. bacteria of the genus Nitobacter) can use nitrate as a source of oxygen and cause denitrification by the liberation of gaseous nitrogen or nitrous oxide. Ammonia also is liberated after flooding as a result of anaerobic breakdown of organic matter, and is often the major source of nitrogen for marsh plants. Phosphorus may be chronically deficient, or may be lost by leaching, but reduction of iron phosphate upon waterlogging may release phosphate into the soil solution. Organic content varies widely, but is usually in the range of 10 to 40% (Odum et al. 1982).

STUDY SITES

Three sites were used in this study; a managed impoundment (IRC #12), an unmanaged, breached impoundment (SLC #23), and a natural unimpounded marsh (Oslo Marsh). At IRC #12, stations were established in the following locations: 1) In an upper marsh flat sometimes covered with Salicornia bigelovii (12R); 2) Approximately 100 m southeast of 12R in an unvegetated upper marsh flat (12O); 3) Approximately 2 m from the perimeter ditch in a Batis-Salicornia stand (12D).

Four stations were established in impoundment SLC #23: 1) Station 23B is located near the perimeter ditch on the south side of the breach; 2) station 23D is located approximately 15 m from the perimeter ditch approximately 250 m south of the breach in an area dominated by black mangroves; 3) station 23N is located in a Batis meadow, approximately 100 m from the perimeter ditch. 4) Station 23S is located within the same Batis stand as 23N, approximately 6 m to the south of 23. Two stations were established at Oslo Marsh, one in the upper marsh, above mean high water (OSE), and the other about ten meter west of the former below mean high water. Both stations were located within Batis-Salicornia stands.

METHODS

Samples were collected on a monthly schedule by inserting a 10.2cm diameter corer into the sediments to a depth of 20 cm. The resulting core was then divided into two equal halves representing 0-10 and 11-20 cm horizons. Each portion was stored in a separate plastic bag for transport to the laboratory. In the laboratory, the samples were spread in labelled aluminum trays, debris was removed from the samples, and large chunks of sediment were manually broken up to facilitate drying. The trays were then stored in an air-conditioned room equipped with a dehumidifier for drying.

After the samples were dry, they were ground with a hand soil grinder, and sieved through a 2mm mesh aluminum sieve. The samples were then packed in paper bags and shipped to the University of Florida's (IFAS) Soil Analysis Laboratory where the following: determinations were performed: concentration of potassium (K), phosphorus (P), iron (Fe), Ammonia (NH_4), nitrate (NO_3), Sodium (Na), and Chloride (Cl); electrical conductivity (EC), pH (pH), and percent organic carbon (OC). Table 5 gives a summary of the samples collected and their status.

DATA

There was considerable temporal variation in most variables measured, as indicated by the high percent of the variance 'explained' by the DATE component (Table 6). Site station and depth were also important. The latter two components will probably gain in importance when the sites are considered independently.

Mean values for the variables measured are shown in Figure 6. Cursory examination of the plots indicates that SLC #23 and Oslo Marsh appear to be more similar to each other than to IRC #12. The latter site had higher Na, Cl, K, EC and OM and lower Fe and P values than the others. The highest mean Fe values and the lowest NO_3 values were recorded at SLC #23, whereas Oslo Marsh tended to have high nitrogen (NO_3 and NH_4) and low sodium.

As mentioned above, no conclusions can be gleaned from these data until the field work is completed and the data set properly analyzed. We will include the results of those activites in upcoming reports.

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Table 1. Mean (S.E.) sulfide concentrations (g-at/l) collected at the different stations and depths. MID = mid-channel, COL = water column.

	COL		15 cm		30 cm		45 cm	
	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.
				BLUE HOLE				
NORTH	-	-	21.18	5.03	70.85	13.25	110.38	12.43
SOUTH	-	-	20.45	5.06	30.21	5.71	76.20	6.62
MID	-	-	136.76	26.32	42.97	22.04	88.99	10.49
COL	0.046	0.012	-	-	-	-	-	-
				IRC #12				
NORTH	-	-	41.39	10.77	47.90	8.70	46.05	5.25
SOUTH	-	-	32.36	8.14	38.59	5.42	51.80	6.27
MID	-	-	203.33	33.56	406.84	36.14	436.52	60.32
COL	0.325	0.131	-	-	-	-	-	-
				TIDAL CREEK				
EAST	-	-	3.29	0.80	9.25	1.19	33.29	5.13
WEST	-	-	3.85	1.18	9.15	1.78	27.42	3.04
MID	-	-	0.59	0.16	1.00	0.43	1.04	0.31
COL	0.057	0.012	-	-	-	-	-	-

Table 2. Results of nested ANOVA for the effects of site (S), station (STA), and sample depth (D) upon the pore water variables measured. W-D indicates the rankings obtained after application of the Waller-Duncan test to the site means. Brackets and parentheses indicate the nesting hierarchy.

FACTOR	F	p≤	W-D
D.O.			
S	5.01	0.007	CREEK > BLUE
STA(S)	0.80	0.573	
D[STA(S)]	0.71	0.806	
TEMPERATURE			
S	11.34	0.001	IRC #12 = BLUE > CREEK
STA(S)	0.73	0.501	
D[STA(S)]	0.95	0.517	
SALINITY			
S	71.55	0.001	IRC #12 > CREEK = BLUE
STA(S)	25.66	0.001	
D[STA(S)]	2.81	0.001	
pH			
S	0.46	0.633	-
STA(S)	0.97	0.444	
D[STA(S)]	0.95	0.521	
SULFIDE			
S	154.38	0.001	IRC #12 > BLUE > CREEK
STA(S)	115.19	0.001	
D[STA(S)]	7.49	0.001	

Table 3. Results of Waller-Duncan tests for differences between stations and depths in salinity and sulfide concentrations at each site. Inequalities are significant at the 0.05 level. NSD = no significant differences ($p > 0.05$).

	STATION	DEPTH
SALINITY[1]		
BLUE HOLE	NSD	45 > 30 > 15
TIDAL CREEK	MID > WEST > EAST	NSD
IRC #12	NORTH = SOUTH > MID	NSD
SULFIDE[2]		
BLUE HOLE	MID > NORTH > SOUTH	45 > 30 = 15
TIDAL CREEK	EAST = WEST > MID	45 > 30 > 15
IRC #12	MID > NORTH = SOUTH	45 = 30 > 15

[1] Station: $F_{6,610}=25.66$, $p \leq 0.001$, Depth: $F_{18,610}=2.81$, $p \leq 0.001$

[2] Station: $F_{6,639}=115.19$, $p \leq 0.001$, Depth: $F_{18,639}=7.49$, $p \leq 0.001$

Table 4. Results of analyses of variance for the effects of site upon surface water salinity, pH, and sulfide. W-D indicates the rankings obtained after application of the Waller-Duncan test to the data.

VARIABLE	F	p≤	W-D
D.O.	1.18	0.314	-
TEMP.	2.24	0.113	-
SALINITY	2.41	0.097	-
pH	3.04	0.050	BLUE = IRC #12 > CREEK
SULFIDE	4.43	0.015	IRC #12 > BLUE = CREEK

Table 5. Summary and status of the samples collected.

DATE	NUMBER	STATUS
1989		
7 December	54	Completed
1990		
9 January	54	Completed
14 February	54	Completed
23 March	54	Completed
26 April	54	Completed
31 May	54	Completed
27 June	54	Completed
25 July	54	Completed
29 August	54	Completed
26 September	54	In Soil Analysis Lab.
29 October	54	In transit to S.A.L.
30 November	54	Drying
27 December	54	To be collected.

Table 6. Variance components for the soil chemistry data. Numbers indicate the percent of the total variance accounted for by the given factor.

VARIABLE	SITE	STATION	DEPTH	DATE	ERROR
K	17.7	2.2	0.0	65.8	14.3
P	13.4	35.4	9.4	30.2	11.7
Fe	18.2	53.9	0.1	17.6	10.2
Na	16.4	6.7	0.6	38.2	38.1
NO_3	5.4	10.6	17.0	45.1	21.9
NH_4	7.7	0.0	12.9	64.5	14.9
Cl	6.2	3.2	0.0	85.5	5.1
EC	42.8	5.7	1.1	40.6	9.9
pH	35.8	21.1	13.8	12.6	16.7

FIGURE LEGENDS

Figure 1. Map of the pore water sulfide study area indicating the sampler layout at each site.

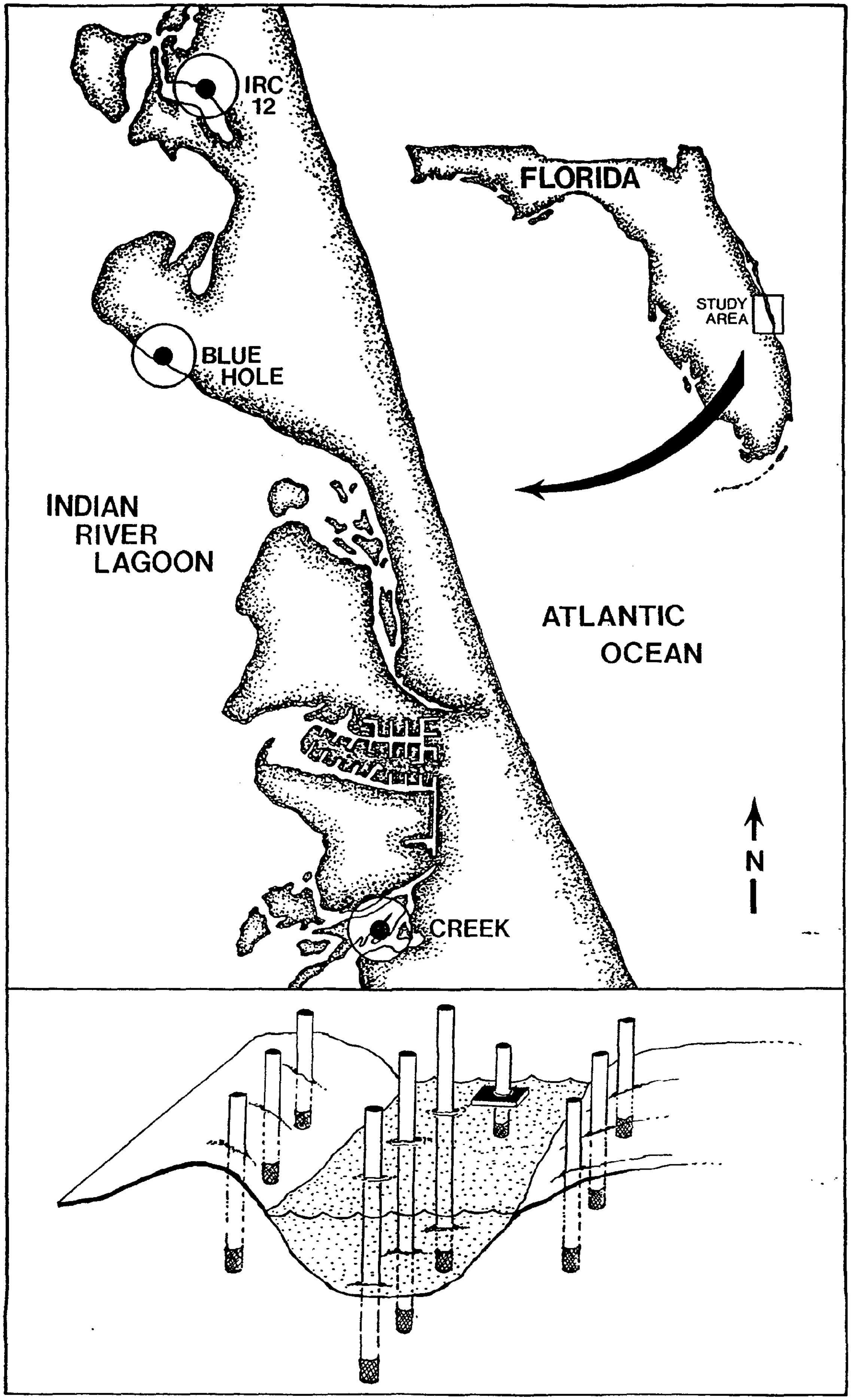
Figure 2. Schematic diagram of the pore water samplers.

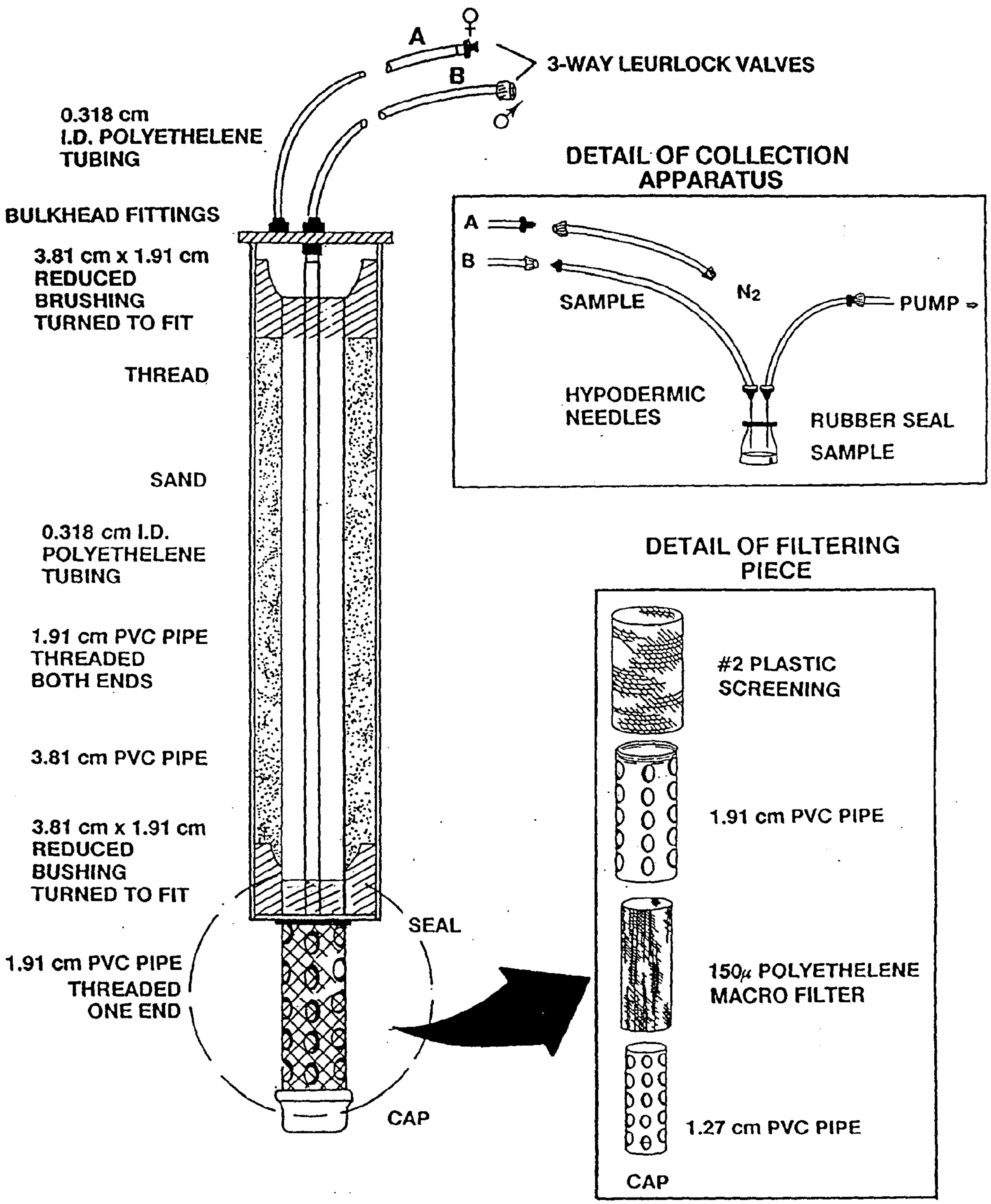
Figure 3. Sulfide concentrations at the bank stations. Circles = 15cm, squares = 30 cm, triangles = 45 cm.

Figure 4. Sulfide concentrations at the mid-channel stations. Symbols as in Figure 3.

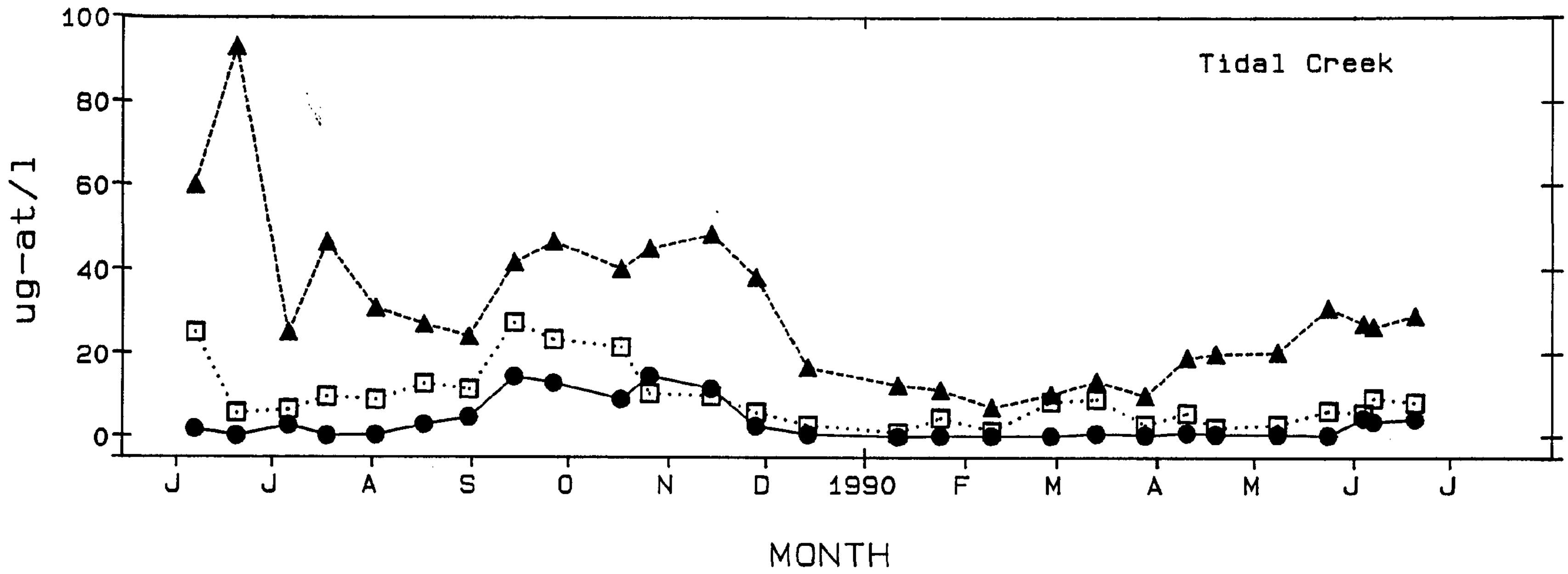
Figure 5. Salinity and sulfide during culvert opening. Symbols as in Figure 3.

Figure 6. Mean values of the soil chemistry variables for the data available so far. (A) EC & pH, (B) NO_3 & NH_4, (C) Na & Cl, (D) Fe & OM, (E) K & P.

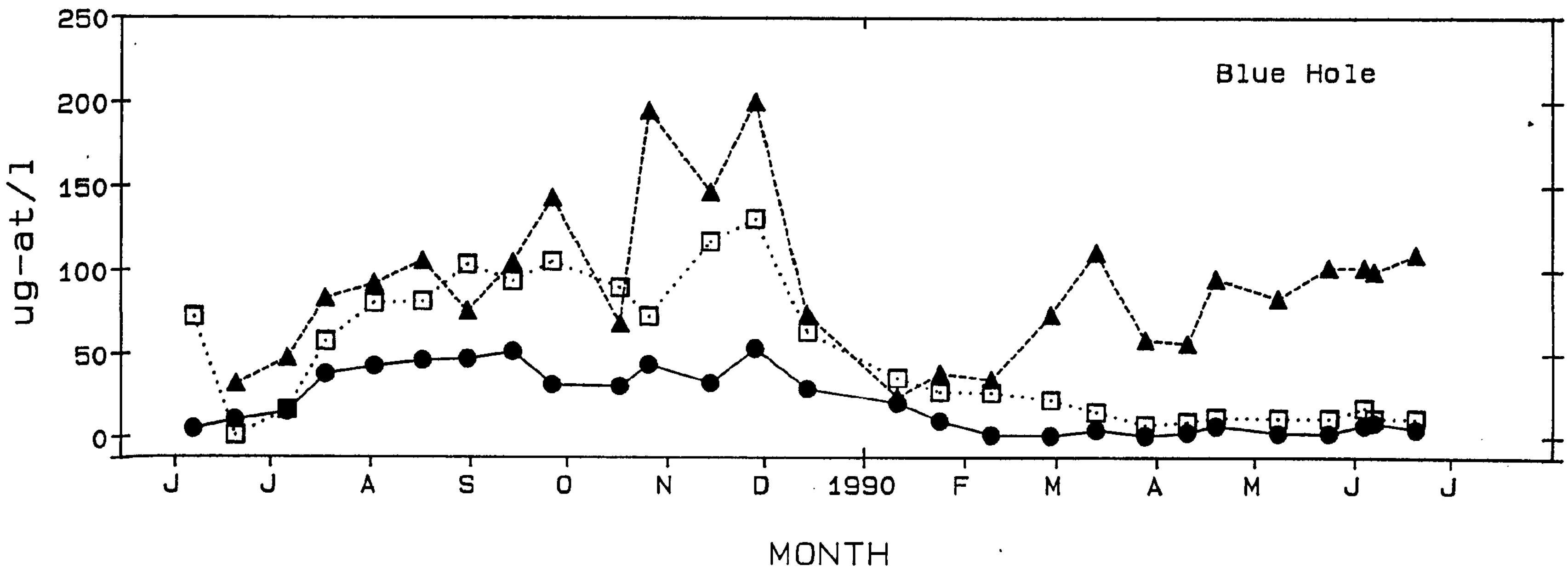

IRC
12
FLORIDA
STUDY
AREA
BLUE
HOLE
INDIAN
RIVER
LAGOON
ATLANTIC
OCEAN
N
A CREEK


A
B
3-WAY LEURLOCK VALVES
0.318 cm
I.D. POLYETHELENE
TUBING
BULKHEAD FITTINGS
3.81 cm x 1.91 cm
REDUCED
BRUSHING
TURNED TO FIT
THREAD
SAND
0.318 cm I.D.
POLYETHELENE
TUBING
1.91 cm PVC PIPE
THREADED
BOTH ENDS
3.81 cm PVC PIPE
3.81 cm x 1.91 cm
REDUCED
BUSHING
TURNED TO FIT
SEAL
1.91 cm PVC PIPE
THREADED
ONE END
CAP
DETAIL OF COLLECTION
APPARATUS
A
B
SAMPLE
N_2
PUMP
HYPODERMIC
NEEDLES
RUBBER SEAL
SAMPLE
DETAIL OF FILTERING
PIECE
#2 PLASTIC
SCREENING
1.91 cm PVC PIPE
150µ POLYETHELENE
MACRO FILTER
1.27 cm PVC PIPE
CAP

3 A,B

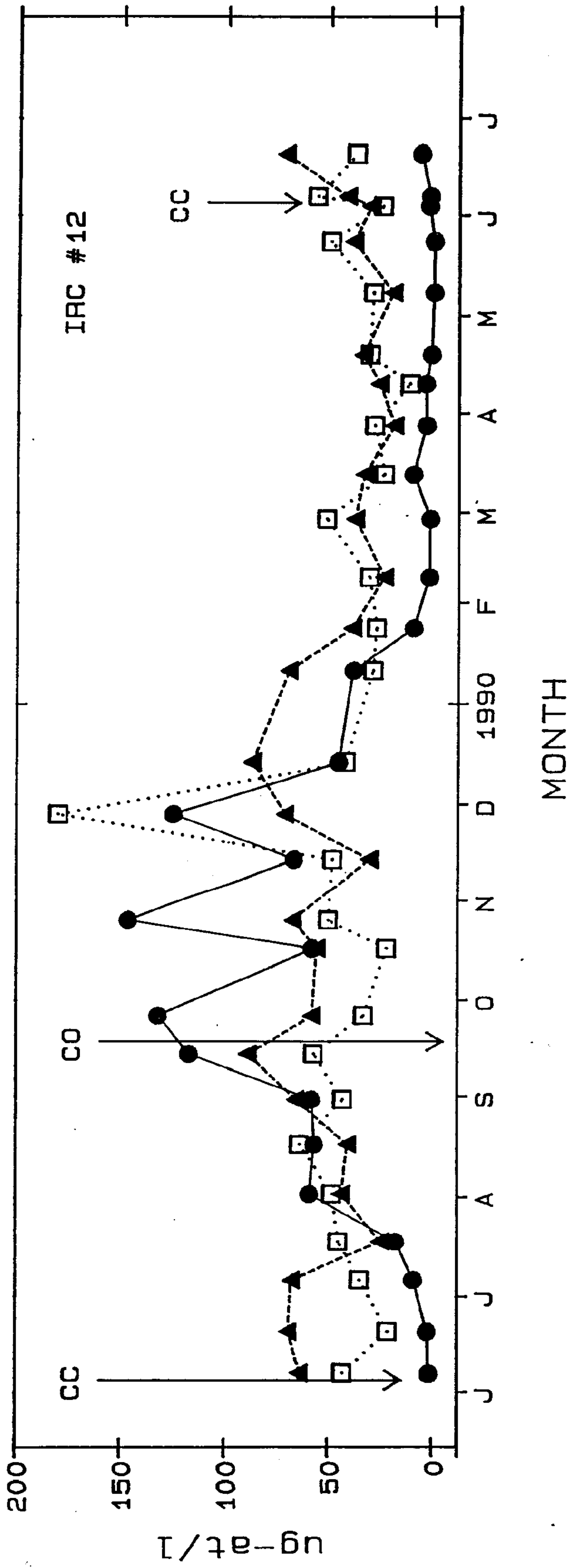


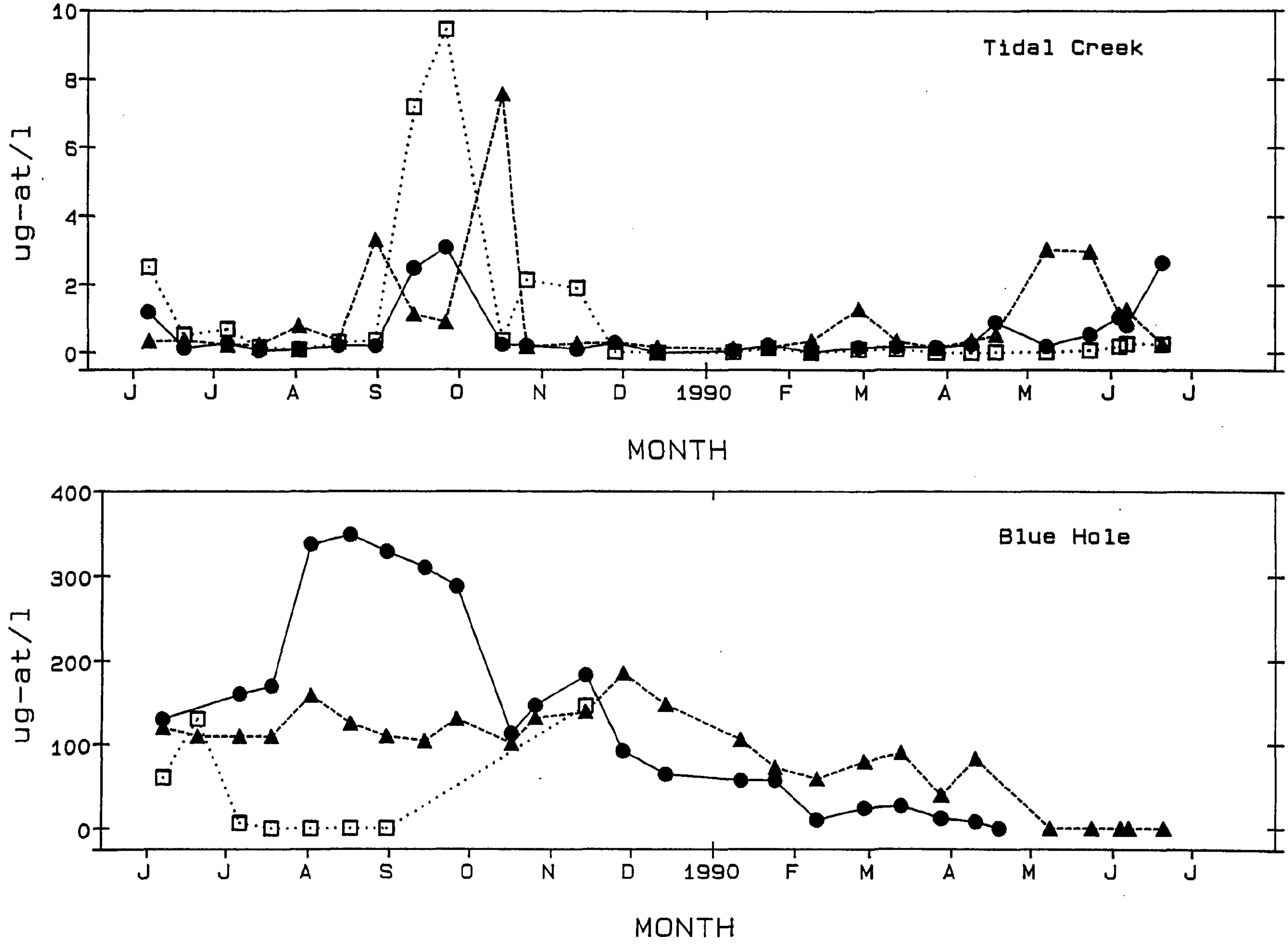
Tidal Creek
ug-at/l
100
80
60
40
20
0
J J A S O N D 1990 F M A M J J
MONTH



Blue Hole
ug-at/l
250
200
150
100
50
0
J J A S O N D 1990 F M A M J J
MONTH

3c

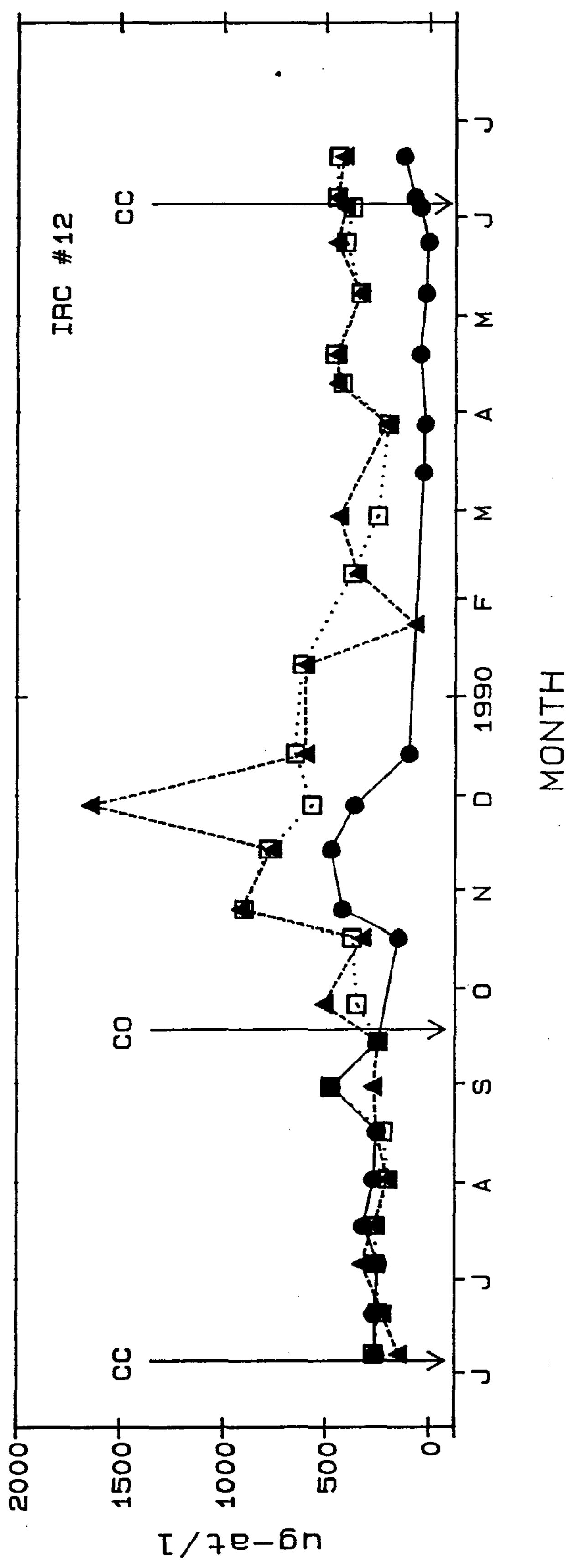

IRC #12
CC
CO
CC
ug-at/l
200
150
100
50
0
J
J
A
S
O
N
D
1990
F
M
A
M
J
J
MONTH

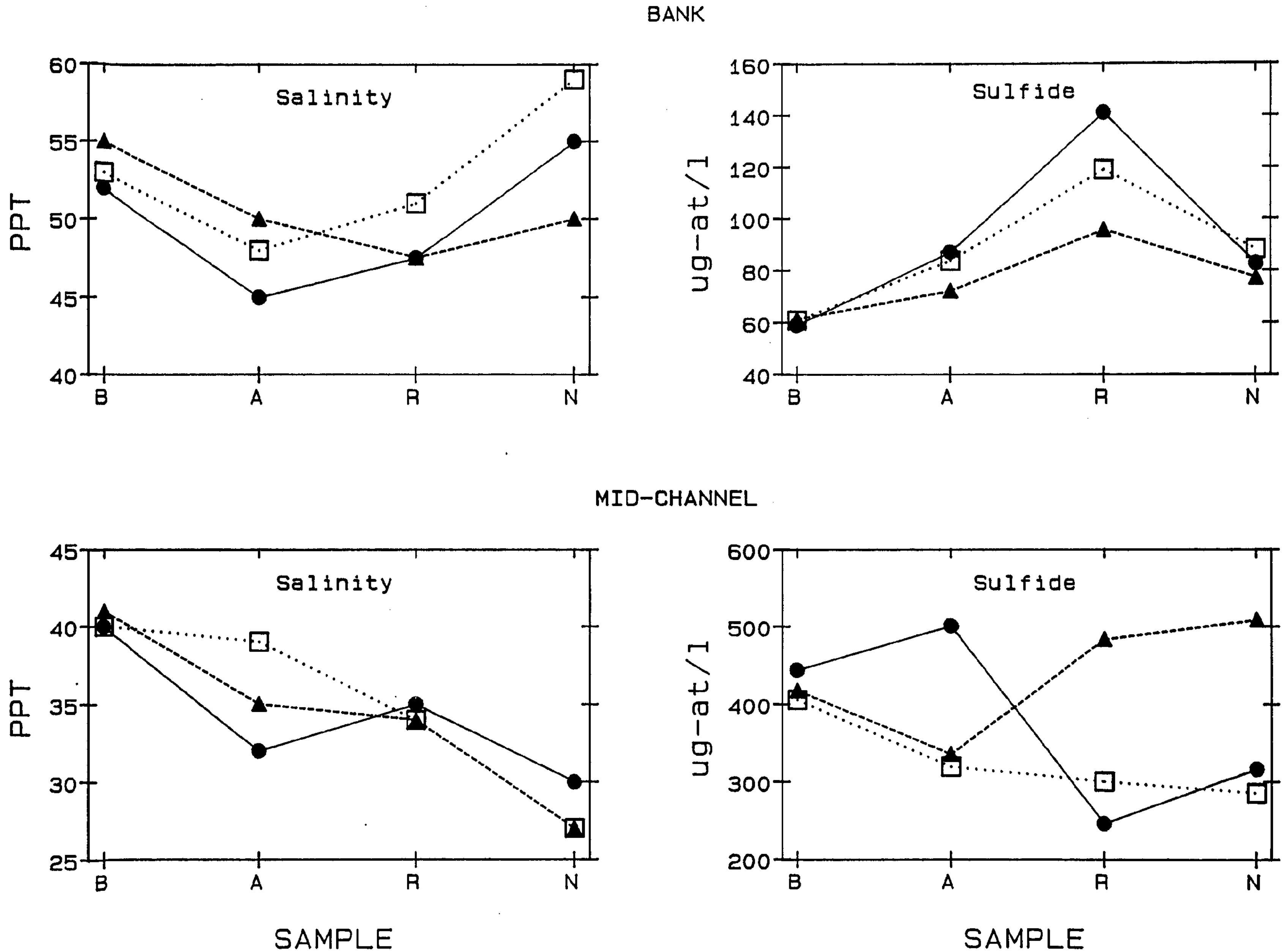


Tidal Creek
ug-at/l
10
8
6
4
2
0
J J A S O N D 1990 F M A M J J
MONTH
Blue Hole
ug-at/l
400
300
200
100
0
J J A S O N D 1990 F M A M J J
MONTH

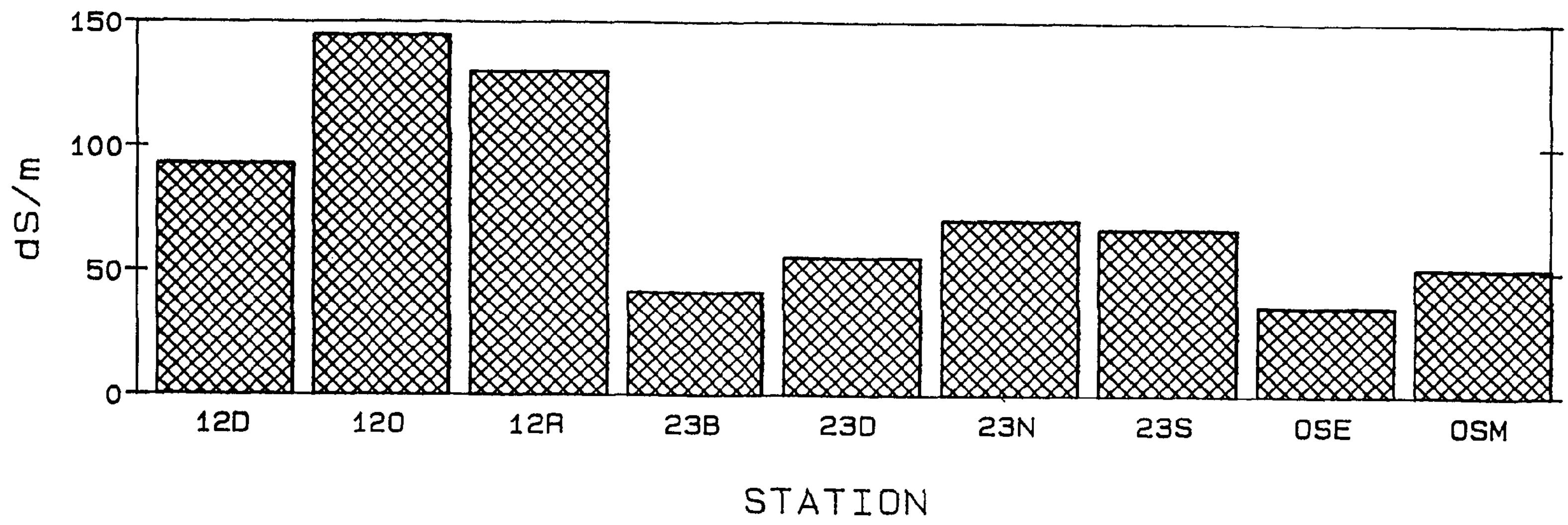
4A,B

4C


IRC #12
CC
CO
CC
J
J
A
S
O
N
D
1990
F
M
A
M
J
J
MONTH
2000
1500
1000
500
0
ug-at/l


BANK
Salinity
PPT
60
55
50
45
40
B
A
R
N
Sulfide
ug-at/l
160
140
120
100
80
60
40
MID-CHANNEL
Salinity
PPT
45
40
35
30
25
Sulfide
ug-at/l
600
500
400
300
200
SAMPLE
SAMPLE

EC



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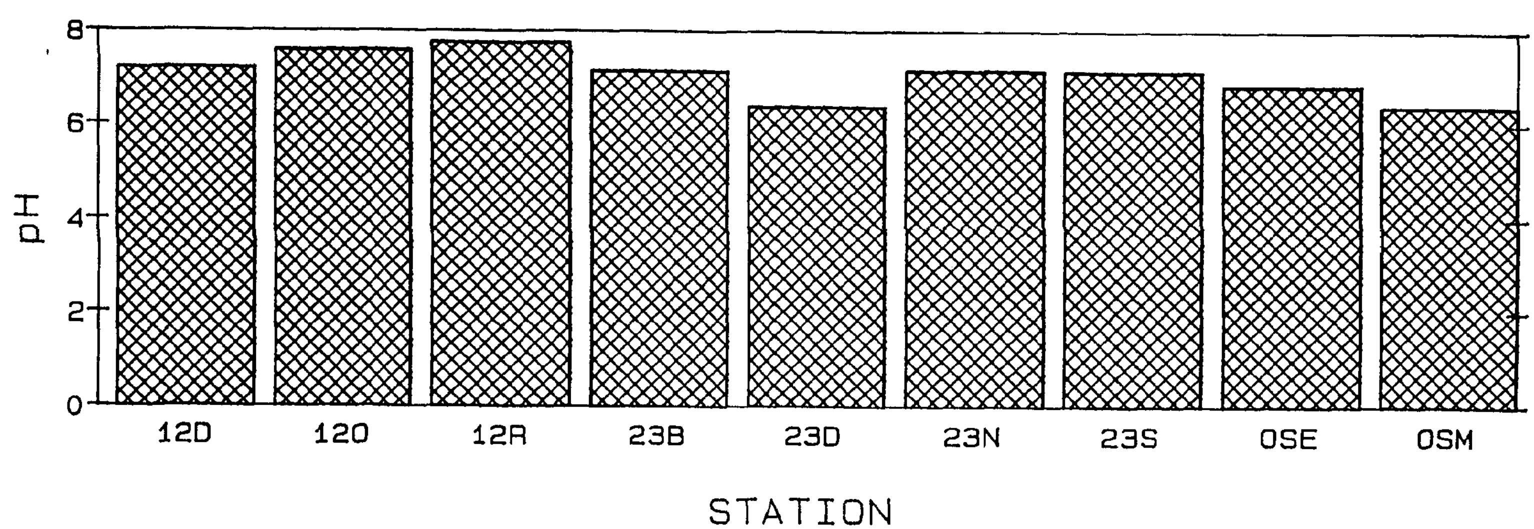
STATION

pH



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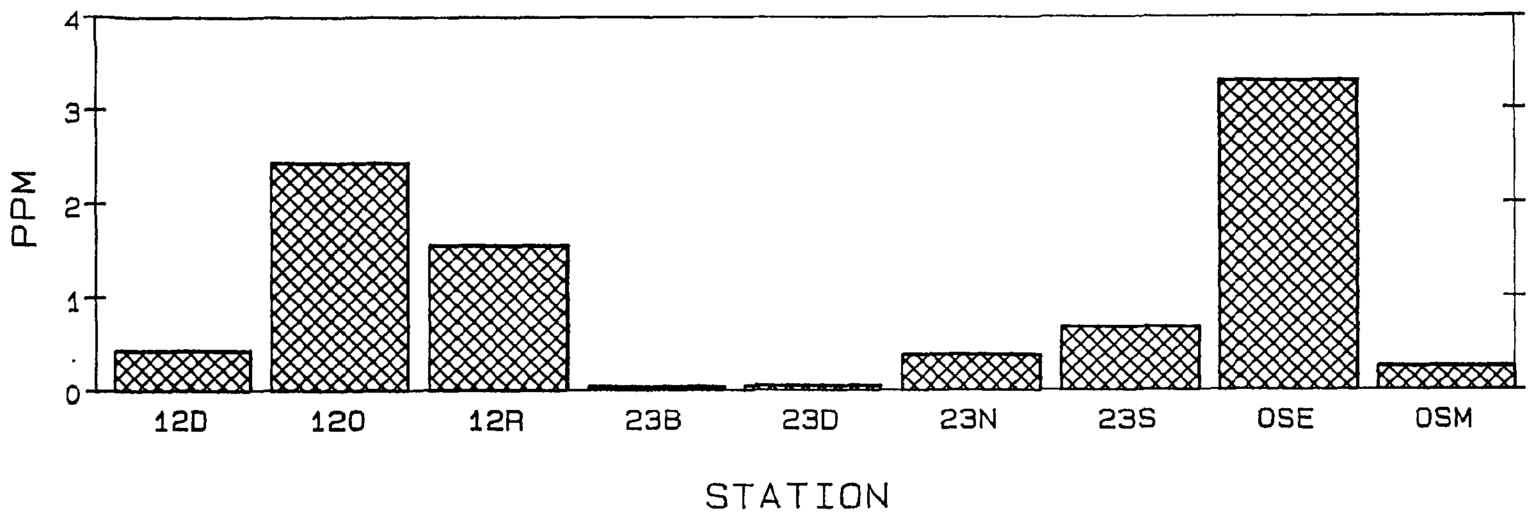
OSM
STATION

6A

N03



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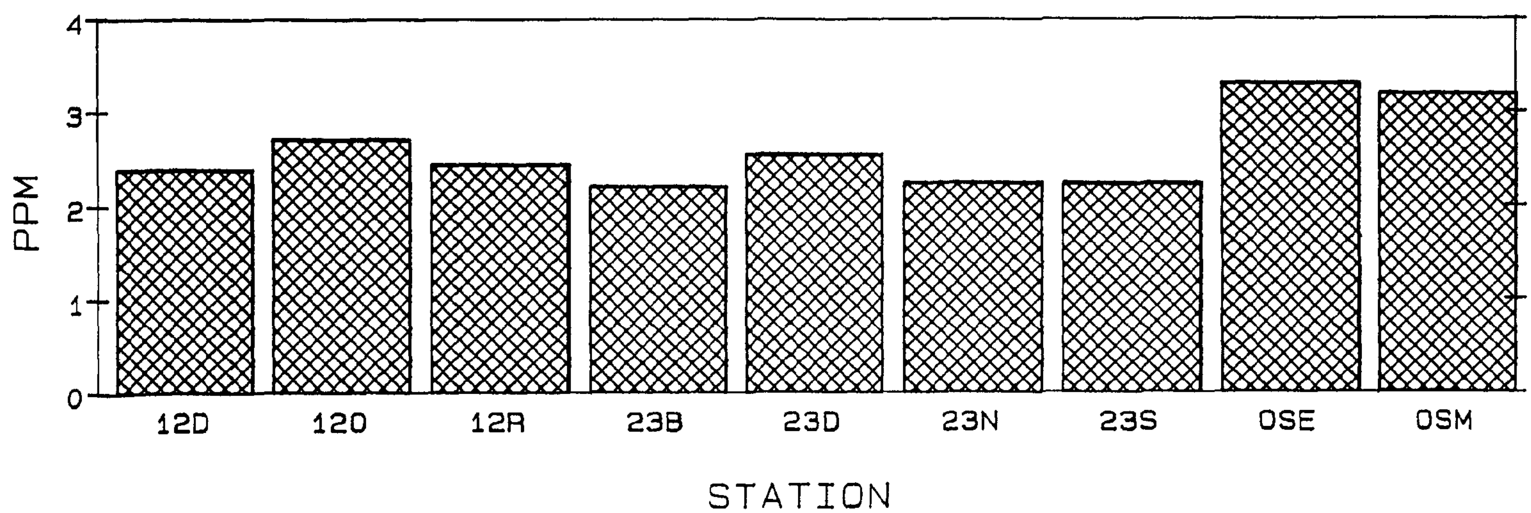
OSM
STATION

NH4



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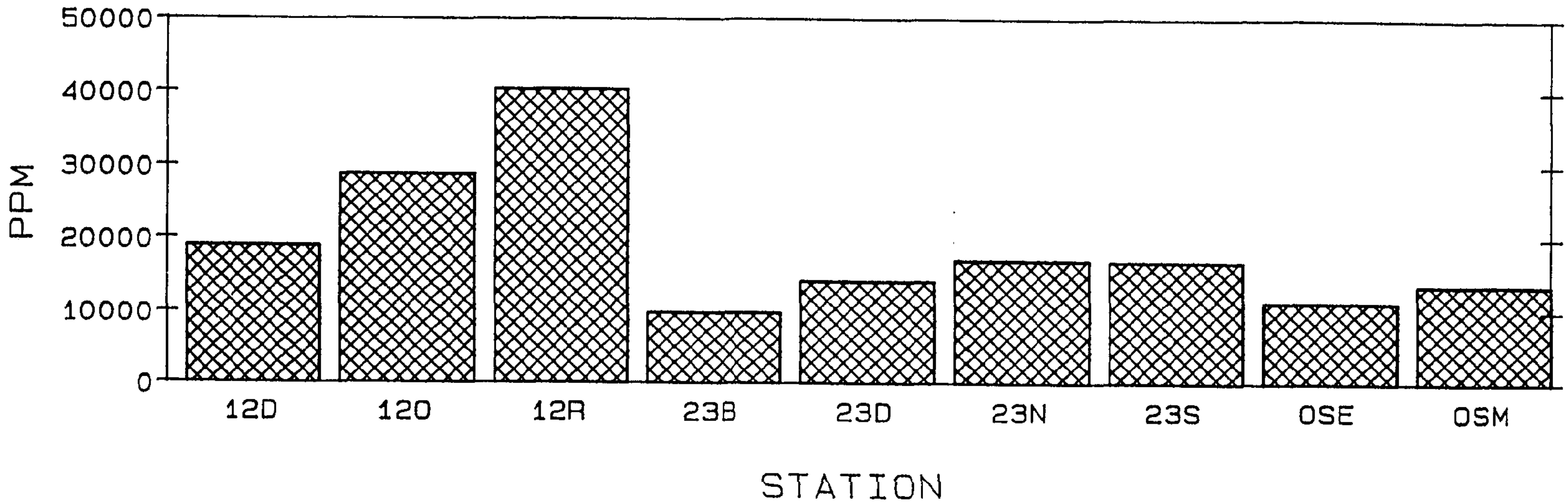
OSE
OSM
STATION

6B

6C

Na



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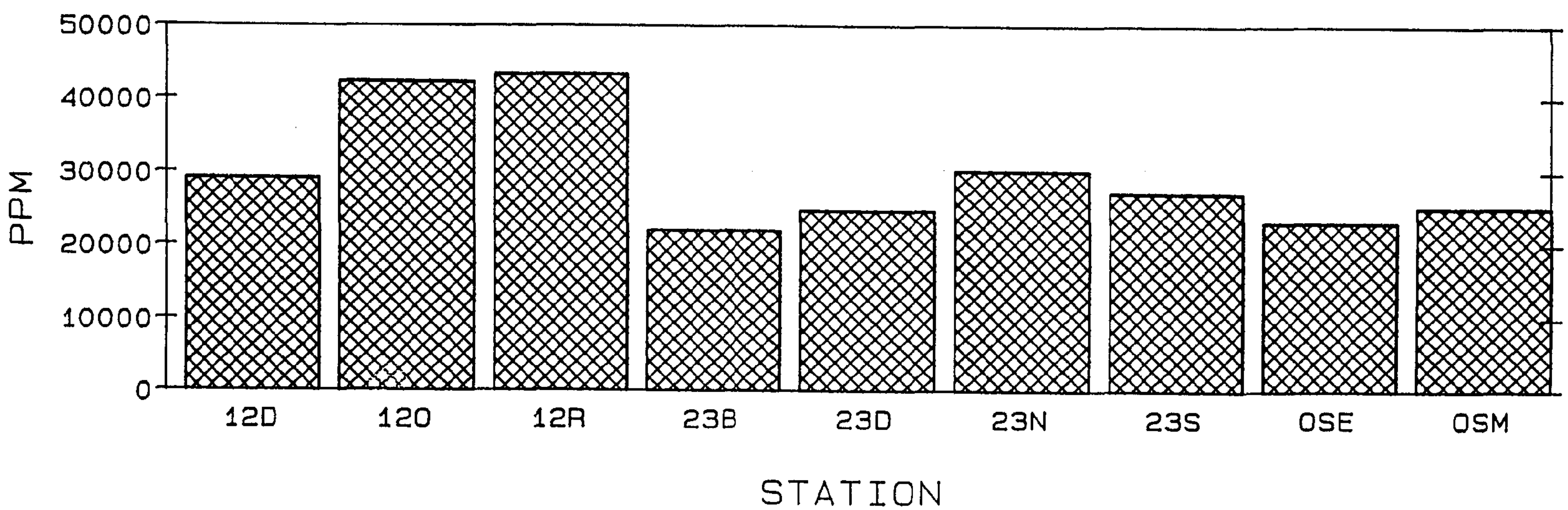

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STATION

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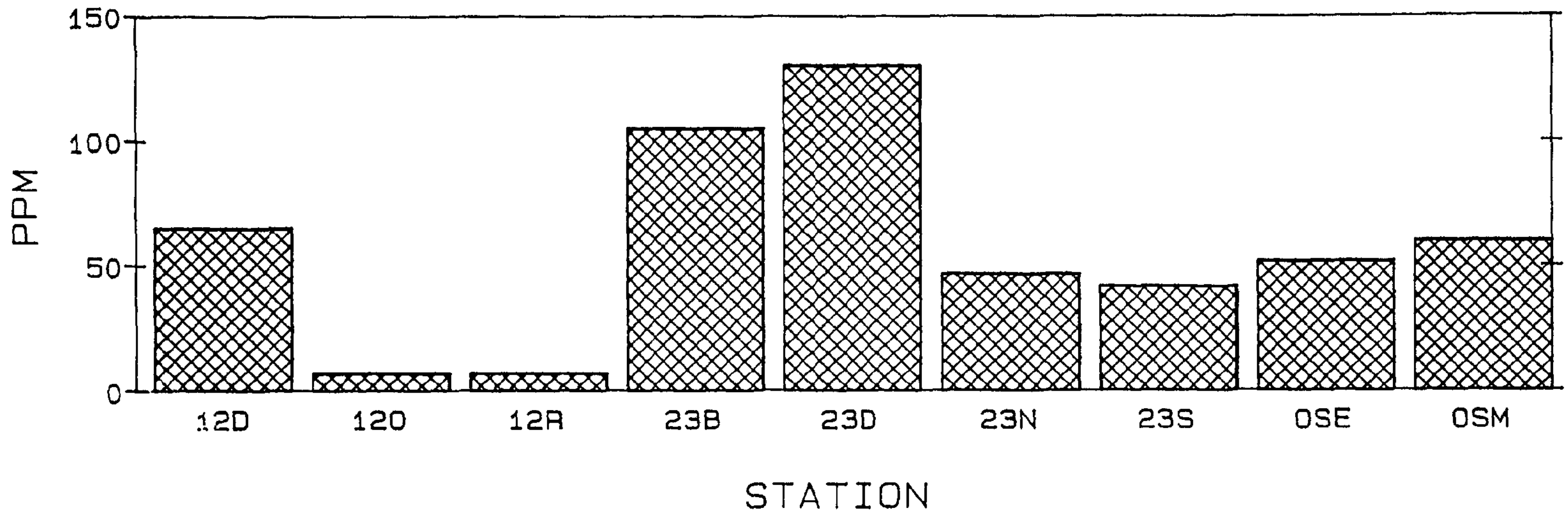

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STATION

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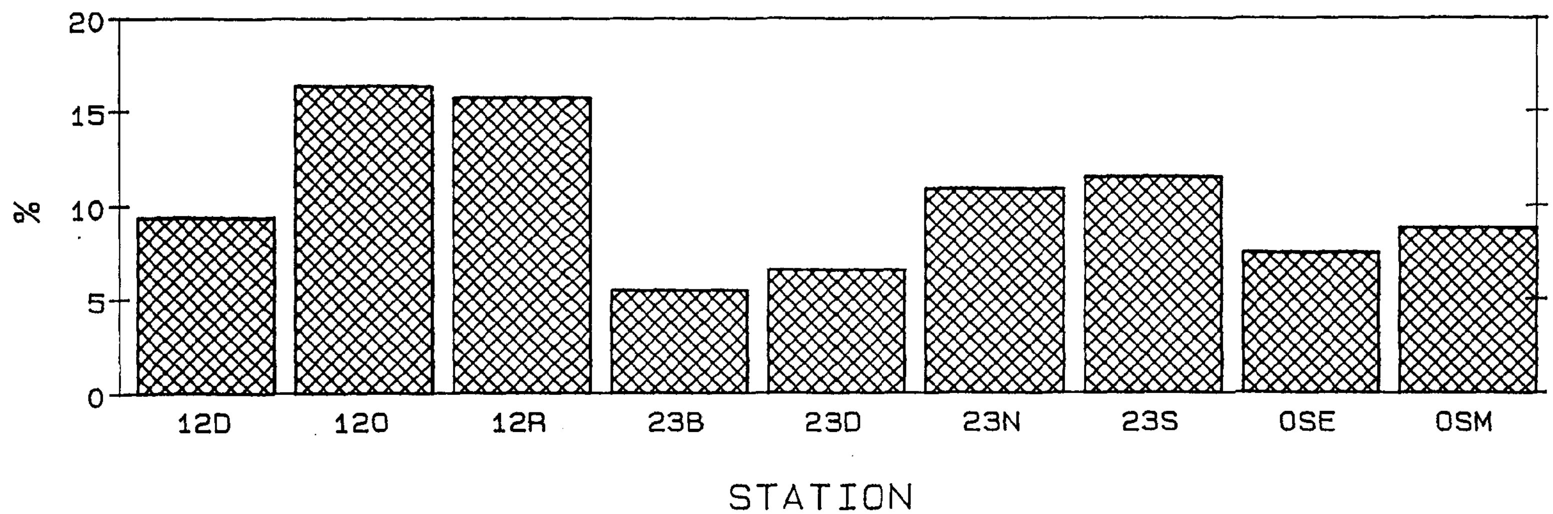

%
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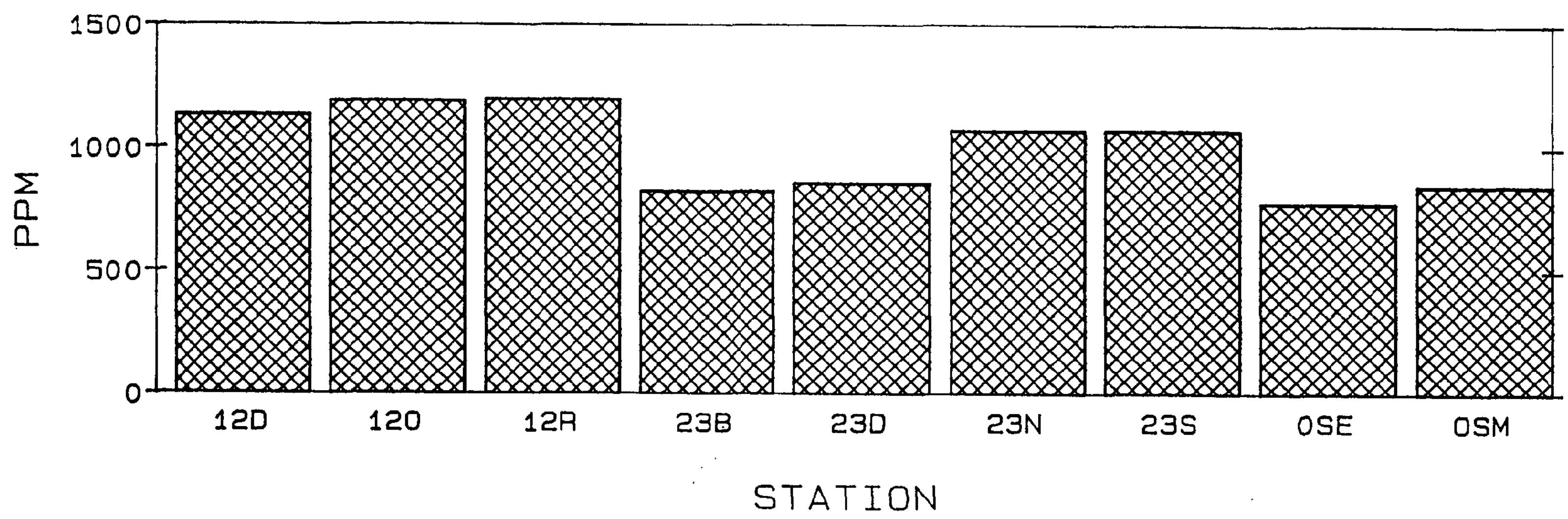
STATION

K



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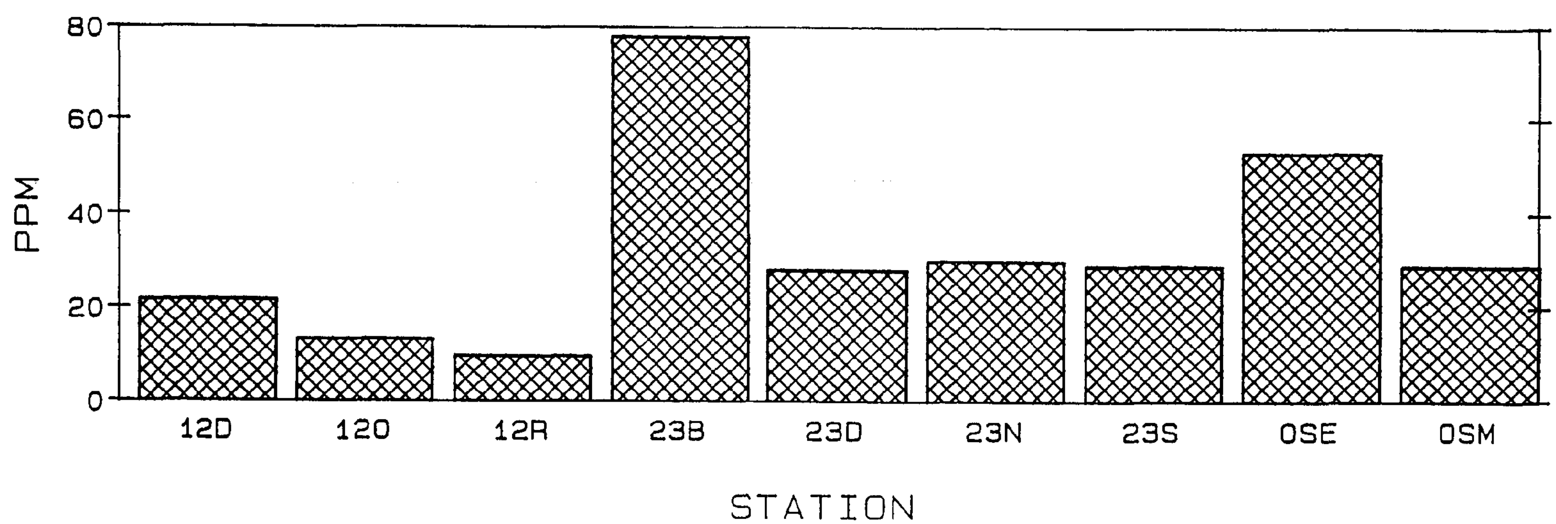
STATION

P



80
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PPM
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OSE
OSM
STATION

6E

Final Report

Spatial and Temporal Dynamics of Secondary Productivity in High Marsh Habitats Vegetated with Algae, Herbaceous and Woody Flora under Natural and Managed Hydrological Cycles

IRCMCD/DER
CM-258

By

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SUMMARY

In summary, positive and negative biological impacts of rotational impoundment management have been documented for high marsh populations of numerically dominant organisms, Cyprinodon variegatus and Uca spp.

1. As a result of competition for space, Cyprinodon move into newly flood areas and establish new territories as the water levels rise.

2. Cyprinodon males are territorial during reproductive periods. At this time they defend a territory of approximately 0.5 m in diameter in shallow water less than 30 cm. Mating occurs within these territories.

3. With flooding, all Cyprinodon observation sites developed an algal mat which is a documented food source for this species.

4. Impoundment flooding under RIM allows breeding on the marsh surface to occur for 3-4 months longer than the period found in tidal areas under natural conditions during fall sea level rise. This results in an increased number of Cyprinodon being produced in impoundments under RIM.

5. High water levels played an important role in the distribution of Uca at all of the study sites. The fall sea level rise, starting in September and continuing until November had a marked affect on the lower elevation transects of all sites. This affect ranged from the complete loss of burrows at the created marsh at Grand Harbor to markedly low densities at the other sites. The upper elevation transects were affected but, not to the extent of the those at lower elevation transects.

6. The RIM management of Impoundment 12 showed a major impact on burrow density and distribution. A complete loss of burrows started at closure in June at the lower elevation transect and continued through the fall sea level rise.

7. Impoundment 12 and the created marsh at Grand Harbor consistently had low densities of Uca year round. Both of these sites have little or sparse vegetation. The other sites are moderate to densely vegetated with mud or sand substrate with Uca present year round.

8. The presence of Uca is important in a wetland ecosystems in the form of bio-turbation, breakdown of plant material and nutrient cycling and as a source of food for secondary consumers. Therefore, rotational impoundment management could have a substantial negative impact on these aspects of wetland ecology.

9. We strongly recommend that the ecological impact on the benthic communities, created by impoundment closure and flooding, be reevaluated. Management should consider reducing the period of time that the impoundment is closed and flooded by delaying flooding and/or opening earlier. The reduction of flood elevation should also be considered.

INTRODUCTION

Recent historical observations on the function of marsh and mangrove swamp ecosystems have demonstrated that the high marsh salterns and algal flats associated with herbaceous halophyte meadows are of great energetic value (Gilmore et al. 1985, 1986a). The algal substrate is consumed by a variety of invertebrates, and transient and resident marsh fishes and is important to the sheepshead minnow which contributes the greatest nekton biomass in regional high marsh ecosystems. There also are considerable differences in high marsh function when it is covered with herbaceous vegetation, than when it is covered with woody vegetation such as the red mangrove, Rhizophora mangle (Gilmore et al. 1986b). Anthropogenic impacts on marsh and mangrove swamp ecosystems on the coast of east central Florida have created a variety of high marsh vegetative communites under artificial hydrological conditions, particularly in association with ditching and impounding for mosquito control (Carlson et al. 1985; Lewis et al. 1985; Gilmore 1987).

Maintenance of standing water over the high marsh for several months preceding the natural inundation has an impact on the high marsh which has not been totally defined. We know that resident fishes disperse across the upper marsh in herbaceous halophyte habitats and consume detrital-algal conglomerates on the surface of the marsh and reproduce. We know another typical high marsh species the fiddler crab, Uca spp., which is also primarily a detrital-algavore may utilizes this same resource under different conditions. Previous meter-square throw net data from impounded high marsh sites under rotational impoundment management (RIM) (Impoundment 12, Indian River County) revealed that Uca was absent from the high marsh in the impoundment while it was present in relatively large numbers at unimpounded sites adjacent to the impoundment.

These animals contribute considerable biomass to the high marsh community and the adjacent estuary during the high marsh exposure periods. They export high marsh primary production through biological transport by emigration or when consumed by a variety of aquatic and terrestrial predators (e.g. snook, tarpon, wading birds, marsh snakes, raccoons and otters [Gilmore and Snedaker in press]). Therefore, there is some concern by various state agencies on the impact of premature and prolonged marsh flooding on the high marsh flora and fauna. This research, conducted simultaneously in natural, impounded-tidal and RIM managed high marsh habitats, was designed to produce a new perspective on the impact of RIM programs on high marsh animal populations.

MATERIALS AND METHODS

Site descriptions: This research was conducted in selected marshes and mangrove forests adjacent to the Indian River lagoon on the east coast of central Florida. These sites were in Indian River and St. Lucie counties. Below is a brief description of each site with information on vegetation, topography, and substrate type.

Indian River County, Florida

Impoundment 12 (Fig. 1) is a 21 ha marsh which is 70% unvegetated with 20% cover of the marsh succulents, Batis sp. and Salicornia, and 10% cover of mixed mangroves (Rey and Kain). The substrate is mostly detrital material with very little live macrophyte vegetative cover. This surface supports a heavy mat of algae when inundated for prolonged periods. Along the eastern upland fringe, there is a band of the marsh succulents mentioned above, grading down into the open marsh surface. The substrate in this band is mostly sand mixed with detrital material. This impoundment is managed under what is called rotational impoundment management (RIM). The impoundment is seasonally closed and pumped, covering the marsh surface with water to control the breeding of the salt marsh mosquitos (Aedes sp.). Under RIM, the impoundment is closed from May or June through September while remaining open to the lagoon via culverts during the rest of the year. This is the only study site where water levels were controlled.

The "north marsh" (Fig. 2) is an unimpounded area just north of IMP 12 that has 2 shallow ditches (less than 0.5 m in depth) that run from the estuary into the high marsh. These ditches are lined with mangroves and are the major man-made impact on the area. Away from the ditches there are broad areas of high marsh dominated by dense, mature-growth marsh succulents with scattered black mangroves. The substrate is a firm mud mixed with sand. This appears to be very nearly what marshes along the estuary in this area were before impounding. There is a filled upland covered primarily with exotic vegetation along the eastern edge of this marsh.

Grand Harbor (Fig. 3; mitigated marsh) is a marsh located within a residential development north of the Vero Beach city limits. This area has a wide variety of marsh types and conditions from relatively unimpacted high marsh areas (similar to north marsh) covered with marsh succulents to totally new "created" marsh mandated as mitigation for the development. In this latter case, the marsh was constructed by scraping the substrate to grade and then planting Batis and Salicornia with a fringe of Spartina alterniflora along the water. This area was also available for recruitment of other vegetation by tidal action during seasonal events. The vegetation in some of this area was sparse. The surface substrate was hard packed sand/clay and included rocks and even marl.

St. Lucie County, Florida

Impoundment 23 or Blue Hole Point (Fig. 4; breached impoundment) is a 122 ha impoundment with a 10m breach in the western dike allowing free tidal access from the Indian River lagoon. The vegetation consists of 50% mixed mangroves and 30% Batis and Salicornia sp. with 20% unvegetated (Rey and Kain). The study area is located on the southern portion of the impoundment. The study area has a very distinct vegetation gradient. Near the water at lower elevations, there is a dense stand of red and black mangroves that grades into a band of marsh succulents as the substrate elevation slowly increases. As the elevations continues to slowly rise, the succulents thin and are replaced by large open areas with scattered small black mangroves (0.5 m). Nearing the upland fringe, there is a second band of Batis and Salicornia that is much denser than the first. The substrate consists mainly of sand with a small amount of detrital material with some muddier areas in the mangroves.

The "tidal creek" site (Fig. 5; natural marsh) is a natural island adjacent to the barrier island near Jack Island State Preserve. The island has a saline tidal tributary to the Indian River lagoon draining its interior. The study area extends from a firm mud zone along the tidal creek with mixed black and red mangroves toward the high marsh. The high marsh consists of dwarf red and black mangroves with about 50% of the area covered by Batis. The substrate consist mostly of sand with little detrital material present. Elevations rise steeply from the fringe to the high marsh and this high marsh may be higher than the other sites listed above.

Fish observations: Observational data on fish behavior and utilization of on the upper marsh surface was conducted during the summer at Impoundment 12, as this was the only study site that was flooded due to water management under RIM. The other sites, the breached impoundment, the mitigated marsh, and the natural marsh, were not flooded until fall under natural hydrologic cycles. The substrate elevation and vegetation at the natural marsh area did not allow comprehensive observations following the methods described here. Observations were taken in ten 10 m X 10 m quadrats located along a transect across the marsh surface from areas of low elevation to higher elevations near the upland fringe. The ten quadrats were broken down into two groups of five at upper and lower elevations. Each quadrat was then broken down into nine equal sections of 11.1 m^2. A computer program was written to randomly determine the group of quadrats (upper or lower) to be observed first and in what order the quadrats within that group would be observed. The program next determined which section within each of the quadrats would be observed. This program was executed once for each transect at each site for each observation date.

At each chosen section within the quadrat, a timed observation was made. After approaching a section, a two-minute acclimation period (Raney et al. 1953; Itzkowitz 1974) was allowed for the settling of disturbed fishes and material in the water. After this acclimation period, a five-minute observation period commenced. During this time, the following activities were scored on the data sheet (Fig. 6): Cruising - a multidirectional movement within or through the study section; Feeding - capture of a prey item or foraging action such as, nibbling on the substrate or vegetation; and Flashing - fish dashing on their side along the bottom resulting in the reflectance of light vertically through the water column (seen as a flash as from a mirror by the observer). Fish position in the water column and numbers of fish observed (estimated by the largest group of fish observed cruising) were recorded along with comments on pertinent environmental factors, including water clarity, weather, and vegetation cover. All of these categories were applicable to all fish species observed: Cyprinodon variegatus, Poecilia latipinna, and Gambusia holbrooki. In addition, two categories of behavior were included specifically for Cyprinodon and need further explanation.

Cyprinodon behavior has been studied in many other locations and habitats by Itzkowitz, Kodric-Brown, Raney et al., and others. Much is known about its life history and the complex behavioral patterns associated with reproduction. The majority of these studies concentrated on the male behavior. Cyprinodon males are aggressive and establish territories during breeding. Itzkowitz has identified three main defensive territorial behaviors that have been classified as chasing, threatening, and patrolling (Itzkowitz 1984). These behaviors define and defend the territory that has been established by the male to attract a female for mating. For our purposes these three behaviors were combined and labeled "defending". A reproductive male is easily identified not only by his behavior but by his bright irridescent blue mating coloration (Itzkowitz 1974). They defend territories that are approximately 0.5 m in diameter from all intruding males and juveniles. The number of these territories which have easily identifiable physical boundaries was recorded. If a receptive female enters the territory, mating may occur. It may, however be interrupted by intruders which distract the breeding male (Itzkowitz 1974 and 1981).

Spawning starts with the female slowly swimming into the territory of a male. The male typically reacts by rapidly swimming toward her as if she were an intruder. Her response is to swim rapidly in small circles, followed closely by the male. The female will abruptly dive to the substrate and take bite out of it. The male positions himself parallel to her making contact with her just behind the operculum. At this point the pair perform the S-shape mating act (thought to be typical for the genus) while the male wraps his tail around her's (Itzkowitz 1974). A rapid vibration of the bodies occurs at which point the eggs are laid (Raney et. al). The mating act may be repeated several times or the female may just leave the territory (Itzkowitz 1974). For our purposes, all of the sequence described above for mating was condensed into a behavior called "mating". All observation data were entered into a computer for analysis.

Observations at Impoundment 12 were taken at various times of day during the closed period. After the impoundment was opened on 24 September, all observations were taken at or near high tide with the exception of those taken on 25 and 26 September at low tide. All other observations at other sites were taken near high tide.

Fiddler crab counts: The data for Uca populations was collected by establishing 2 transects at each of the 5 sampling sites (Figs. 1-5). These transects were separated from the fish observation areas to reduce the habitat disturbance in all of the areas. Transects were 15 m in length with stakes placed at the 0, 5, 10, and 15 m marks. These transects were oriented with respect to the topography of the marsh with 0 m being the lowest elevation. At each site, a "lower" transect started at or near the waters edge and proceeded onto the marsh surface, while an "upper" transect started on the surface and proceeded to the upland fringe. The exception to this procedure occurred at Grand Harbor where one transect was in a mitigated area; the other was in a more natural area dominated by saltwort and glasswort; and both were at "lower" elevations. A 1 m^2 frame was tossed at random in the area between each pair of stakes (i.e. 0 m and 5 m, 5 m and 10 m) and in the same manner in the 5 meter area beyond the 15 m stake in the upland direction. All Uca borrows within the frame were counted and recorded. A total of three replicate tosses were made in each area. Where the frame could not be thrown because of vegetation, an object such as a golf ball was thrown to establish a corner and the frame laid down from that point.

RESULTS

Fish observations:

Impoundment 12

The number of behaviors observed for Cyprinodon increased over the course of the closed period at Impoundment 12 (Figs. 7-11; Table 1). All of the individual behaviors followed this trend to some degree, as did the number of territories and the estimate of the number of fish present. There was a lag of almost 2 months after closure on 6 June before numbers of fish began to show noticeable increases. Near the end of July there was a gradual increase in the numbers of observations of cruising and flashing from near 0 to peaks in September in the thousands (Figs. 7 & 8). Groups observed cruising included juveniles and adult males and females. In mid August the first aggressive defending behaviors were observed in the lower transect followed the next week by defending in the upper transect (Fig. 9). The first territories followed the same trend with lower preceding upper by approximately a week (Fig. 10). The number of territories rose much higher much faster in the lower transect. However, the number of territories in the upper transect did surpass the number in the lower reaching over 70 on 13 September, but decreased to near 0 within days. A similar decrease occurred in the lower transect, but it lagged behind the upper by several days (Fig. 10). Defending behavior followed much the same trend (Fig. 9). These events and peak number estimates (Fig. 11) occurred just prior to impoundment opening on 24 September.

After opening, the first 2 days of observation (25 and 26 September) were conducted on or near a low tide. The observations made 26 September illustrated the differences in elevation in the two transects. The upper transect was dry except for a few puddles (about 1 cm in depth) with almost no fish, while areas in the lower transect had up to 5 cm of water and 1000 fish (Table 1).

Subsequent sampling on high tides showed that different behaviors responded differently to the presence of tides. Cruising and flashing tended to follow the average water levels closely and were still present in large numbers (Figs. 7 & 8). Defending behavior, as stated above, decreased just prior to opening and except for a few scattered observations never recovered. These scattered observations only occurred when the average water level was near or above the 30 cm mark (Fig. 9). Territories were also absent except for 12 found in quadrat 2 on the lower transect on 31 October and 1 in each of 2 quadrats in the upper transect on 7 November. Both of these dates had average water levels near 30 cm.

Gambusia were present more frequently in the lower transect, but the greatest numbers of cruising and feeding events per timed observation occurred in quadrat 1 on the upper transect (Table 1). Gambusia were present in 63 time observations in the lower transect and were present in only 31 in the upper transect. Five of the 6 observations of 100 or more cruising or feeding events, including an observation of 300 cruising events, occurred in the first quadrat of the upper transect. This quadrat is immediately adjacent to an upper marsh pond.

Poecilia was present in only 27 timed observations with the majority occurring in the lower transect (20). The only behavior that was observed was cruising with a maximum of 62 of these events occurring in a single lower transect observation. The total number of cruising events for all timed observations was 132.

Blue Hole Point

With the fall sea level rise in mid September, the marsh surface at Blue Hole Point began to be tidally flooded and observations commenced. By mid November tides no longer reached the marsh surface and observations ceased. During this entire time however, water was never present in quadrats 4 and 5 of the upper transect. These 2 quadrats were in the upper band of marsh succulents and into the upland fringe. Observations in quadrat 1 of the lower transect were occasionally obstructed by the presence of mangroves.

The first Cyprinodon were observed on 17 September with large numbers of cruising and feeding events occurring in the lower transect and lower quadrats of the upper transect (Table 2). This date had the largest total number of behaviors observed in the lower transect in three categories, cruising, feeding, and flashing (1196, 423, and 188, respectively; Figs. 12, 13, & 14). It was also the peak for the estimated number of individuals (90) for the lower transect combined (Fig. 15). Maximums for the upper transect combined were reach in cruising and feeding behaviors and total numbers on this date as well (Table 2; Figs. 12, 13, & 15). Nearly all of these behaviors occurred in quadrat 1 which has the lowest elevation in the upper transect. There is no clear trend in these behaviors through the rest of the period except for their ultimate decline as water levels recede.

Aggressive defending behavior and territories were only present during one time observation at Blue Hole Point. On 2 October, 6 territories were being defend in quadrat 2 in the lower transect (Fig. 16). A total of 92 individual defensive behaviors were observed in this one 5 minute period. On this date fish were present in other quadrats, but none were exhibiting this behavior.

Gambusia were regularly observed cruising in the lower transect with some quadrats having as many as 38 events being noted (Table 2). These larger numbers were observed in October. Poecilia were virtually absent with on 5 cruising events recorded throughout this period.

Grand Harbor

The Grand Harbor transects were established just after the fall sea level rise, and were sampled beginning on 4 October. The observations were done at the transects in conjunction with the monitoring program being conducted at that location. These observations were done at roughly two week intervals in association with lunar cycles. A total of 4 observations were made before water no longer covered the marsh on high tide. Quadrat 5 on the upper transect was at a high elevation and was not flooded during this period.

Numbers of behaviors observed for Cyprinodon were highest on the second and third observation date (Table 3). No Cyprinodon were observed on the first trip and overall numbers of behaviors were greatly reduced by the fourth date. Cruising and flashing account for the majority of the behaviors observed with feeding being important on some occasions. The largest number of cruising events occurred on 18 October with 592 being counted in the lower transect quadrats combined. In the upper transect, the largest total for cruising occurred on the same day with 246 events being recorded (Table 3). Flashing followed the same trend. The peak number of flashing behaviors occurred in quadrat 2 on the lower transect again on 18 October. The greatest number of feeding events occurred 2 weeks later on 2 November with 120 being counted in quadrat 4 of the lower transect. Overall many more of the above 3 behaviors were recorded from the lower transect (Table 3).

All of the defending behavior observed was seen in November. The first and largest observation of defending behaviors coincided with the peak in feeding behavior cited above. Quadrat 4 of the lower transect was the location for 25 aggressive defending events. Two weeks later on 19 November, 8 more such events occurred in quadrat 2 of the upper transect.

Gambusia and _Poecilia_ seemed to be the pioneers into the newly flooded marsh in early October. The largest numbers of cruising events occurred on 4 October. On this date, all quadrats with water in both transects had cruising events numbering from 32 to 157. Their number declined with the coming of November and were gone as the water receded.

Natural Marsh (tidal creek)

The topography and vegetation at the natural site made it impossible to do the same systematic observations as were done at the other locations. Several qualitative observations were made at gain as much information as was practical. At the highest tide observed at the site, water was only a thin sheet over the central part on the high marsh. Very small 6 to 8 mm fish were seen swimming for puddle to puddle. Upon collection, these fish were identified as _Poecilia_. In the transition area between the mangrove fringe and the high marsh, small to moderate sized _Cyprinodon_ (15-30 mm) were observed in among the dense vegetation. No distinct behaviors could be observed.

Uca (Fiddler Crab) Burrow Density:

Impoundment 12

The data collected at Impoundment 12 (Fig. 17; Table 4) showed for the lower transect that a low density of _Uca_ burrows were present from December to May and are absent June to November. The highest density reached in the lower transect was 15 burrows/m^2 in December in the 10-15 m quadrat. During the period from June to November zero _Uca_ burrows were present in all four quadrats. From December to May the 10-15 m and 15+ m quadrats had higher monthly densities than the 0-5 m and 5-10 m quadrats. The 5-10 m quadrat showed the lowest densities on a monthly basis with values staying below 5 burrows/m^2 during the December to May period.

In the upper transect the 0-5 m and 5-10 m quadrats consistently had densities below 6 burrows/m^2 (Fig. 17; Table 4) from December to June and zero burrows from July to November. The 10-15 m quadrat reaches a high density of 25 burrows/m^2 in December and a low of 10 burrows/m^2 in April for the December to May period. During the June to November period the 10-15 m quadrat showed a sharp decline, from 13 burrows/m^2 in June to zero burrows in September and October. For the 15+ m quadrat during the December to May period, the high density was 14 burrows/m^2 in January and the low 11 burrows/m^2 in March. For the June to November period the density did not reach zero, the lowest density reached 3 burrows/m^2 in October and a high density of 24 burrows in August. For November at both the 10-15 m and the 15+ m quadrats the density increased, where in the 0-5 and the 5-10 m quadrats the density remained zero.

When comparing water level data for Impoundment 12 (Fig. 17) it must be considered that this site is managed under RIM. During the months June to September, the impoundment is closed off from tidal access and the marsh surface flooded and the water level maintained at a higher level than normal. The remainder of the year, October to May, the impoundment is open to tidal access allowing the marsh surface to be tidally flooded during the fall months and the marsh surface exposed during months of low water levels.

At the lower transect, Uca burrows were present from December to May when the water levels were low and the marsh surface exposed. Starting in June when the impoundment was closed under RIM and the surface was continually flooded to 33 cm and above, burrow densities dropped to zero and remained zero through November in all Quadrats. The data for the upper transect showed that, for the 0-5 m and 5-10 m quadrats burrows were present from December to May. However, starting in June and continuing to November the density dropped to zero. The 10-15 m quadrat had burrows present from December to August, but, in September and October zero burrows were present and less than 5 burrows/m^2 appeared in November. The 15+ m quadrat had burrows present during all months with a low of less than 3 burrows/m^2 in October.

North Marsh

The data for the lower transect (Fig. 18; Table 5) showed a general pattern of high densities in December, which declined monthly until May, when the densities increased through August. After the fall sea level rise, burrow densities dropped to zero except for a very small number of burrows in October. The 0-5 m quadrat showed the lowest densities relative to the other quadrats consistently from December to August. The highest densities occurred in December in the 5-10 m, 10-15 m and 15+ m quadrats were densities ranged from 80 to 90 burrows/m^2. During the December to August, period the lowest density, 10 burrows/m^2 occurred in May in the 0-5 m quadrat. For all four quadrats a density of zero occurred during the months of September and November. For the month of October the 5-10 m, 10-15 m and the 15+ m quadrats had less than 5 burrows/m^2 and the 0-5 m quadrat zero.

The data for the upper transect (Fig. 18; Table 5) showed highest densities in December which declined until May, then a slight increase occurred with burrows present until November. The highest density for the transect occurred in the 10-15 m quadrat, with 79 burrows/m^2, the lowest density occurred in September with values of zero for the 0-5 m, 5-10 m and 10-15 m quadrats. The 15+ m quadrat consistently had the lowest densities except for September.

The north marsh is an unimpounded marsh where the affects of tidal influence will only be a factor during fall sea level rise. In September as the fall sea level rise occurred (Fig. 18) the lower transect burrow density reached zero for all of the quadrats. In October when the water level was still rising, burrows were present in the 5-10 m, 10-15 and the 15+ m quadrats but, in densities of 4 burrows/m^2 or less. As the sea level rise continued the density again fell to zero in all quadrats. The influence of water level is not as dramatic upon the upper transect. In September at the start of fall sea level rise, the 0-5 m, 5-10 m and the 10-15 m quadrats density dropped to zero, the 15+ m quadrats had a density of 3 burrows/m^2. For October and November, burrows were present where densities ranged from 1.6 to 13.3 burrows/m^2.

Tidal Creek

The data for the lower transect (Fig. 19; Table 6) showed a general pattern of high densities in December which declined until May when the densities increased through August, and from September to November there was a marked reduction in densities. The highest density recorded was 113 burrows/m^2 in December in the 0-5 m quadrat. During the December to August period, May had the lowest densities recorded for all quadrats with 13 burrows/m^2 being the lowest in the 10-15 m quadrat. From September to November the density ranged from zero and to 13 burrows/m^2.

The data for the upper transect (Fig. 19; Table 6) showed a general pattern of high densities in December which declined until May when the densities increased through August, and from September to November there was a marked reduction in densities. The highest density 59 burrows/m^2 occurred in December in 0-5 m quadrat. During the December to August period, May had the lowest densities recorded for all quadrats with 10 burrows/m^2 being lowest in the 5-10 m quadrat. From September to November the densities ranged from zero to 45 burrows/m^2.

In September when the water level rose (Fig. 19) above 24 cm burrow density dropped markedly and in December as the water level receded burrow density increased. In September, at both transects the burrows in the 0-5 m quadrat disappeared.

Blue Hole Point

At this location, sampling did not begin until April, when a suitable site was established. At the lower transect (Fig. 20; Table 7) no well defined pattern appeared except for the complete loss of burrows in November. The highest density, 40 burrows/m^2 occurred in August in the 15+ m quadrat. The 0-5 m and 5-10 m quadrats both had zero burrows in October and November while the 10-15 and 15+ m quadrats reached zero only in November.

The upper transect (Fig. 20; Table 7) had burrows present during all months sampled, April to November, with no distinct pattern. The highest density, 34 burrows/m^2, occurred in November in the 0-5 m quadrat. The lowest density, 1 burrows/m^2, occurred in September in the 0-5 m quadrat.

In October as the water level exceeded 25 cm (Fig. 20) burrows started to disappear in the lower transect in the 0-5 m and 5-10 m quadrats. In November as the water level exceeded 30 cm all four quadrats were affected. The water level had no marked affect on the upper transect.

Grand Harbor

The created marsh transect had rather low densities from December to August with a slight spike in August, from September to November the density dropped to zero (Fig. 21; Table 8). The majority of the quadrats from December to August had a density of 10 burrows/m^2 or less. The highest density 52 burrows/m^2 occurred in August in the 10-15 m quadrat. From September to November, all quadrats recorded a density of zero.

The natural marsh transect showed the same general pattern of high density in December which declined until April-May and then increased slightly until September when the density dropped markedly or to zero in certain quadrats. In August a density of 40 burrows/m^2 or greater was recorded for all quadrats. During the December to August period, the lowest density, 13 burrows/m^2, was recorded in May in the 10-15 m quadrat. In September the density reached zero in all four quadrats. In October burrows returned to all four quadrats. In November only the 0-5 m quadrat had burrows present.

In the created marsh transect as the water level reached 19 cm in September, the burrow density reached and remained zero through November. In the natural marsh transect as the water level rose in September, the burrows disappeared and then returned in October at a lower density. In November, burrows only remained in the 0-5 m quadrat.

DISCUSSION

Considerable emphasis has been placed on the determination of organism population dynamics, spatial and temporal distributions in various wetland habitats, including the high marsh ecosystems of the Indian River Lagoon (Gilmore et al. 1985, 1986a, b, & c, 1987). However, very little work has been done on the behavior and activities of individual organisms qualifying their roles in their respective habitats. This information is important in interpreting the function of habitats and microhabitats in the life history of the organism. Knowledge of the man's influence on the biological activities, behaviors and organism association with microhabitats is critical if enlightened management of whole ecosystems such as impounding and flooding of high marsh and mangrove forest habitats is to take place in a responsible manner. It is not enough to know the structure or description of an animal community under man's influence. One must know the activities influenced before obtaining an understanding of the relationship between ecosystem management and natural ecosystem function.

Fish Behavior:

One of our principle objectives in this research program was to determine fish microhabitat associations and to document individual behaviors of fish in high marsh habitats in an impoundment under rotational management, a breached tidal impounded wetland and an undisturbed wetland. This objective required the development of new techniques for fish observation. The sheepshead minnow, *Cyprinodon variegatus*, numerically dominated the high marsh open substrate and herbaceous study sites and was the principle fish under study. The data obtained has allowed an initial understanding of individual fish behavior and site selection relative to feeding, schooling and reproduction.

Before impoundment closure for rotational management, the population of *Cyprinodon* was at some equilibrium in the perimeter ditch at Impoundment 12. As the water level rises at pump up, the amount of habitat available to this population increased dramatically. The flooding of the marsh surface relieves the potential limitation on the population caused by competition for space in these territorial breeders. This flooded condition also supplied a virtually unlimited food source in the developing algal mat. These two factors are likely the reasons for the dispersal and rapid population growth in *Cyprinodon* observed over the summer and fall in the closed impoundment. In addition, the otherwise harsh conditions in the impoundment during summer (Gilmore et al. 1982) for which the *Cyprinodon* is so ideally suited, has the effect of limiting aquatic piscine predators and other fish which might compete with them for resources. Mating was only observed once during this study, but all information from the literature indicates that if territories are being defended, mating is occurring. This is a logical conclusion considering the immense numbers of *Cyprinodon* collected by Gilmore and colleagues in previous studies in this habitat (Gilmore et al. 1986a & c, 1987).

In the initial period after impoundment flooding, the delay before the observation of fish in the transects may be the result of the dispersal pattern documented by Gilmore et al. (1986c, 1987). The numbers of fish in the perimeter ditch diluted into the vast acreage available after flooding could make it unlikely that fish would be observed in any one location. However, it may be caused by *Cyprinodon* utilizing the area closest to the perimeter ditch for breeding first and, after reaching some increased density, move further onto the high marsh surface. Competition for breeding territories may contribute to the spread of Cyprinodon across the marsh surface. Competition for food and the increases in the available food resource on the marsh surface may also be a factor. With the development of the algal mat after flooding, food would be available throughout the impoundment.

Following the same theory, defending behavior and territories would occur closer to the perimeter ditch first. This was the case. However the upper transect ultimately contained a higher number of territories, indicating a more favorable habitat for breeding there. Defending behaviors and territories decline with the first influence of tides in the fall, but it is possible that this trend may have been exaggerated by a decrease in water clarity. When defending occurred after opening, the mean daily sea level was at or near 30 cm which insured coverage of the high marsh surface by water.

In the tidal areas, the high marsh surface habitat was not available until the fall sea level rise. This allowed approximately 2.5 to 3 months for Cyprinodon to utilize this resource. Cyprinodon were defending territories at both Grand Harbor and Blue Hole Point in October or November. Flooding at lower elevations at these sites also produced optimum resource conditions and algal mat growth. At Grand Harbor's transect site, which is in a mitigated area, the algal mat was very thick and in some places left the bottom and formed floating rafts of material which in some case hindered observations.

At Blue Hole Point, the highest numbers in all categories occurred in the lower transect. This area was covered by water first and for the longest time. The lowest elevation quadrat in the upper transect had the most behaviors of all categories found in this area. Defending behavior was restricted to quadrat 2 of the lower transect. This quadrat, being one of the lowest in elevation, was flooded more frequently for longer periods of time. Grand Harbor followed the same trends, but the defending behaviors first occurred almost one month after those at Blue Hole Point. Numbers of all behaviors observed at these tidal sites never reach the levels recorded in Impoundment 12.

Uca (Fiddler Crab) Burrow Density:

The role of Uca in Florida marshes and mangrove habitats have been generally ignored in the past. Thus, the importance of Uca in the ecology and energetics of the salt marsh and mangrove forest ecosystems have not been considered in the management of impoundments in Florida. The work of Teal (1958, 1962), Wolf et al. (1975), Krueter (1976) and Macintosh (1982) all discuss the important role that Uca play in the the ecology of the marsh in forms of cycling plant material, turning over soil and contributing greatly to the biomass export from the ecosystem. The distribution of the fiddler crab Uca is worldwide with the most species found in tropical regions. At least six species including Uca pugnax, U.pugilator, and U.rapax have been documented in regional wetlands.

The distribution of Uca within the wetland habitat is complex with soil composition and vegetation cover playing important roles. Teal (1958), illustrated these distributions in relation to a Georgia salt marsh. The results from Teal's study showed that biotic and abiotic factors along a elevation gradient directly affected Uca distribution. The slight changes in elevation could be linked to changes in tidal influence which affects soil composition and plant communities which create microhabitats or zones that are preferable to a certain species of Uca. Tidal patterns are also found to be important in the reproductive cycle of at least one species, Uca pugilator (Christy 1978) a common local species found in the area of study.

As illustrated in the results, high water levels played an important role in the distribution of Uca at all of the study sites. The fall sea level rise, starting in September and continuing until November had a marked affect on the lower elevation transect at all sites. This affect ranged to the complete loss of burrows at Impoundment 12 and Grand Harbor created and markedly low densities at the other sites. The upper elevation transects were affected but, not to the extent of that observed at the lower elevation transect.

The flooding of Impoundment 12 during RIM showed a major impact in burrow density and distribution. In the lower elevation transect a complete loss of burrows started at impoundment closure in June and continued through the fall sea level rise. The 0-5 m and 5-10 m quadrats in the upper elevation transect also exhibited this pattern. When compared to sites with tidal influence, North Marsh, Tidal Creek, Blue Hole Point and Grand Harbor (Figs. 18-21) Uca burrows density is impacted mostly by the fall sea level rise period. Also at all of the tidally influenced sites except for Grand Harbor created, the densities are much higher than at the RIM managed site (Fig. 17)..

The impact of water level fluctuations on Uca burrow density is directly related to the topography and elevation of the marsh surface. The higher the marsh elevation the higher water level is required to flood the marsh. Within sites a relative comparison of elevation between transects can be established. The results of fall the sea level rise on the Uca burrow density illustrates that the upper transect is higher in elevation than the lower transect. The exception to this comparison is at Grand Harbor were the elevation of the created marsh and the natural marsh does not appear to be the major factor in Uca burrow density.

The vegetation and substrate play an important role in distribution and zonation of Uca species within a marsh (Teal 1958). The complex relationship of these factors to each species is too complex in scope to be dealt with in this study. The role of Uca populations will be treated as a community in its contribution to the wetland ecosystem.

When comparing vegetation and substrate between sites only general inferences can be made due to the limited quantitative and qualitative data for these parameters at the study sites. Impoundment 12 and Grand Harbor created (Figs. 17 & 21) are the two sites with consistently low densities of Uca year round. Both of these sites have little or sparse vegetation. In the lower transect at Impoundment 12 the there is no vegetation cover, in the upper transect the 0-5 m and 5-10 m quadrats are devoid of vegetation and the 10-15 m and 15+ m quadrats have a fringe of Batis. The loss of vegetation at Impoundment 12 is the result of long term flooding before the implementation of RIM. At Grand Harbor created, this marsh was constructed as a mitigation site. The vegetation is sparse with mainly planted Batis and Salicornia and a Spartina fringe. The substrate at Impoundment 12 is mostly detrital material with very little macrophyte vegetative cover, where the upper transect is mostly sand mixed with detrital material. The substrate at Grand Harbor created is very hard packed material which includes rocks and marl. The North marsh and Grand Harbor natural are very similar in vegetation and substrate, both of these sites are dominated by dense, mature stands of Batis with a firm mud mixed with sand substrate. Also similar in vegetation and substrate are the Tidal Creek and Blue Hole Point sites. These sites are moderately vegetated with patches of Batis and mangroves. The substrate is mostly sand with very little organic material.

The Uca distribution among these sites show similarities when comparing vegetation and substrate. The Grand Harbor created and Impoundment 12 sites, both have greatly impacted vegetation and show low densities throughout the year. Both of these sites substrates do not meet the profiles listed in the literature (Teal 1958) for suitable habitats for Uca. The sites with dense vegetation especially Batis and firm mud with sand substrate show similar trends and densities. Also at these sites were there is large productivity of plant material, there is very little leaf and plant material present on the marsh surface. The sites with predominately sand substrate show similar density patterns. These sites also have very little plant material present on the marsh surface. All of these sites appear to be favorable habitat for Uca except for Grand Harbor created and Impoundment 12. To make comparison to any greater detail without taking into account the different species component of the Uca population at each site would be misleading.

One of the most common trends present at all sites, even though it was muted at Grand Harbor created was the decline of density from December to May with density increasing from then. The spawning period for Uca generally ranges from late spring to early fall (Teal 1958; Christy 1978; Macintosh 1982) and the populations may die off over the winter. This would account for the increase in Uca burrow density starting in May and the decline from December. Christy (1978), showed the importance of the influence of tidal patterns and rhythms in the reproductive cycle of Uca. The study showed breeding was in synchrony with tidal rhythms to maximize tidal movements to transport larvae to optimum habitat for settlement. The non-tidal condition at Impoundment 12 during the summer may have a affect on the transport of larvae out of and into this site.

The ecological importance of Uca can best be explained by Macintosh (1982): "Fiddler crabs turn over the surface sediment layer while feeding, Thereby exposing fresh surfaces to physical and chemical action. Kraeuter (1976) estimated that fiddler crabs and Littorina snails completely reworked the surface sediment each year in Georgia salt marshes. Macintosh (1980) observed the same phenomenon on mangrove shores where Uca were abundant...It can be inferred from these findings that fiddler crabs play a significant role in recycling organic matter and minerals in both salt marsh and mangrove swamp ecosystems." The marsh surface during the study showed evidence of this activity.

The contribution to the ecosystem in the form of biomass is another important role of Uca. To further quote Macintosh, "Fiddler crabs are also an important food source for terrestrial and aquatic predators...It is also believed that fiddler crabs may be consumed by fish entering salt marshes and mangrove swamps during high tides...Predation intensity on Uca populations has not been studied adequately, but for comparative purposes it may be assumed that most of annual production by Uca is consumed by predators." Also the work of Rozas and LaSalle (1990) showed that Uca was a major prey item consumed by Fundulus grandis (gulf killifish). To further reinforce the importance of Uca as a food source we observed evidence of raccoon (Procyon lotor) excavation of Uca burrows on the marsh surface.

CONCLUSION

It is obvious from these observations that rotational impoundment management has a differential impact on the two principle species under study the sheepshead minnow and the fiddler crab, Uca spp. Sheepshead minnow breeding and feeding habitat is made accessible earlier and for longer periods of time in managed impoundments allowing more individuals to be produced in the managed impoundment. The number of fish produced in the tidal areas is dependent on the period of natural inundation of the high marsh as prolonged flooding of pristine high marsh may increase production of fish. As a result, populations will vary with the annual variability of sea level rise.

Fiddler crab populations are influenced in the opposite manner as high water periods coincide with reduced populations on the high marsh surface. The fall sea level rise affected Uca density by reducing the populations at most sites. The flooding of Impoundment 12 in June for RIM reduced the Uca populations to zero. Hydrological events also play a role in the reproductive success of Uca by using tidal transport of larvae to optimum habitat. Sites that are vegetated and have substrates of mud or sand proved to be the most suitable habitat. The importance of fiddler crabs in wetland ecology could be quite critical in substrate dynamics and overall benthic biomass production. These organisms play a significant trophic role and fill an important part in the wetland food chain.

Management Recommendations:

The Uca (fiddler crab) observations bring to light the concern for rotational impoundment management impacts on benthic invertebrate and floral communities which may influence the overall productivity of the impounded wetland. We strongly recommend that the ecological impact on the benthic communities created by impoundment closure and flooding be reevaluated. Management should consider reducing the period of time that the impoundment is closed and flooded, by delaying flooding and/or opening earlier. The reduction of flood elevation should also be considered.

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FIGURE 18. Average number of _Uca_ burrows per m^2 for each quadrat by date at North Marsh with mean daily water level.

FIGURE 19. Average number of _Uca_ burrows per m^2 for each quadrat by date at Tidal Creek with mean daily water level.

FIGURE 20. Average number of _Uca_ burrows per m^2 for each quadrat by date at Blue Hole Point with mean daily water level.

FIGURE 21. Average number of _Uca_ burrows per m^2 for each quadrat by date at Grand Harbor with mean daily water level.

TABLE 1. Impoundment 12 Cyprinodon observations. Local = study site, tran = transect, quad = quadrat, su = section 1-9 within each quadrat, depth = water depth in the section in inches, cyp = Cyprinodon behavior observations which include; cr = cruising, de = defending, mate = mating, no = number estimate for minimum density in each section, ter = number of observed territories established. Gam and Poe = Gambusia and Poecilia behaviors.

							cyp							gam		poe		
local	date	time	tran	qua	su	depth	cr	de	mate	fd	fl	no	ter	cr	fd	cr	fd	comments
Imp 12	07/26/90	10:30	lower	1	2	NA	0	0	0	0	0	0	0	0	0	0	0	poor vis
Imp 12	07/26/90	10:51	lower	2	2	NA	0	0	0	0	19	NA	0	3	0	0	0	
Imp 12	07/26/90	10:37	lower	3	4	NA	0	0	0	0	5	NA	0	2	0	0	0	poor vis
Imp 12	07/26/90	10:44	lower	4	5	NA	0	0	0	0	0	0	0	4	0	0	0	poor vis
Imp 12	07/26/90	10:59	lower	5	6	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	07/26/90	11:15	uppe	1	7	NA	1	0	0	0	0	1	0	0	0	0	0	shallow/clear
Imp 12	07/26/90	11:36	uppe	2	1	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	07/26/90	11:43	uppe	3	4	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	07/26/90	11:29	uppe	4	5	NA	3	0	0	0	15	NA	0	0	0	0	0	
Imp 12	07/26/90	11:22	uppe	5	8	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	07/31/90	11:32	lower	1	3	NA	3	0	0	0	0	NA	0	0	0	0	0	
Imp 12	07/31/90	11:08	lower	2	5	NA	0	0	0	0	0	0	0	1	0	0	0	
Imp 12	07/31/90	11:17	lower	3	8	NA	0	0	0	0	1	1	0	0	0	0	0	
Imp 12	07/31/90	11:24	lower	4	5	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	07/31/90	11:00	lower	5	7	NA	8	0	0	0	0	NA	0	0	0	7	0	
Imp 12	07/31/90	11:43	uppe	1	1	NA	35	0	0	0	26	30	0	0	0	0	0	
Imp 12	07/31/90	12:07	uppe	2	6	NA	37	0	0	0	16	25	0	0	0	0	0	
Imp 12	07/31/90	11:51	uppe	3	7	NA	17	0	0	0	33	10	0	0	0	1	0	
Imp 12	07/31/90	12:15	uppe	4	1	NA	50	0	0	0	1	30	0	0	0	0	0	
Imp 12	07/31/90	11:59	uppe	5	9	NA	0	0	0	0	0	0	0	0	0	0	0	foamy
Imp 12	08/01/90	15:01	lower	1	5	NA	4	0	0	0	2	NA	0	0	0	0	0	
Imp 12	08/01/90	14:44	lower	2	2	NA	11	0	0	0	4	NA	0	0	0	0	0	
Imp 12	08/01/90	15:09	lower	3	9	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	08/01/90	14:52	lower	4	1	NA	12	0	0	0	4	NA	0	2	0	0	0	
Imp 12	08/01/90	15:17	lower	5	6	NA	1	0	0	0	0	1	0	0	0	0	0	
Imp 12	08/01/90	15:55	uppe	1	1	NA	0	0	0	0	3	0	0	0	0	0	0	
Imp 12	08/01/90	16:02	uppe	2	2	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	08/01/90	15:30	uppe	3	8	NA	0	0	0	0	4	0	0	0	0	0	0	
Imp 12	08/01/90	15:47	uppe	4	4	NA	8	0	0	0	17	NA	0	0	0	0	0	
Imp 12	08/01/90	15:38	uppe	5	8	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	08/08/90	15:48	lower	1	8	NA	7	0	0	0	76	NA	0	17	14	0	0	poor vis
Imp 12	08/08/90	15:40	lower	2	6	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	08/08/90	15:33	lower	3	4	NA	0	0	0	0	8	0	0	1	1	0	0	
Imp 12	08/08/90	16:03	lower	4	9	NA	0	0	0	0	0	0	0	0	0	0	0	dense vegitation
Imp 12	08/08/90	15:56	lower	5	5	NA	1	0	0	0	2	1	0	0	0	0	0	
Imp 12	08/08/90	14:34	uppe	1	8	NA	261	0	0	0	97	50	0	0	0	0	0	
Imp 12	08/08/90	15:12	uppe	2	9	NA	8	0	0	0	53	NA	0	0	0	0	0	
Imp 12	08/08/90	14:42	uppe	3	7	NA	8	0	0	0	22	NA	0	0	0	0	0	
Imp 12	08/08/90	14:49	uppe	4	5	NA	107	0	0	0	53	100	0	0	0	0	0	rain/only 2.5 min observation
Imp 12	08/08/90	15:19	uppe	5	9	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	08/09/90	14:43	lower	1	7	NA	0	0	0	0	0	0	0	0	0	0	0	poor vis/foam
Imp 12	08/09/90	14:11	lower	2	4	NA	2	0	0	0	3	1	0	0	0	0	0	
Imp 12	08/09/90	14:35	lower	3	7	NA	8	0	0	0	24	NA	0	1	0	2	0	
Imp 12	08/09/90	14:19	lower	4	6	NA	63	0	0	0	36	30	0	0	0	0	0	
Imp 12	08/09/90	14:27	lower	5	4	NA	197	0	0	0	117	30	0	2	0	0	0	territories established outside tran
Imp 12	08/09/90	15:18	uppe	1	9	NA	220	0	0	0	93	100	0	50	100	0	0	
Imp 12	08/09/90	15:25	uppe	2	9	NA	56	0	0	0	113	20	0	0	0	0	0	poor vis
Imp 12	08/09/90	15:33	uppe	3	5	NA	108	0	0	0	58	60	0	0	0	0	0	poor vis
Imp 12	08/09/90	15:09	uppe	4	7	NA	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	08/09/90	15:02	uppe	5	4	NA	0	0	0	0	0	0	0	0	0	0	0	

TABLE 1 Continued

local	date	time	tran	qua	su	depth	cyp cr	cyp de	cyp mate	cyp fd	cyp fl	cyp no	cyp ter	gam cr	gam fd	poe cr	poe fd	comments
Imp 12	08/15/90	12:08	lower	1	6	NA	54	12	0	0	11	20	2	6	0	0	0	poor vis/foam
Imp 12	08/15/90	11:50	lower	2	4	NA	137	27	0	0	107	40	6	3	0	0	0	many terr's/few defended
Imp 12	08/15/90	12:17	lower	3	8	NA	12	7	0	0	107	5	1	25	0	0	0	
Imp 12	08/15/90	11:41	lower	4	9	NA	1	0	0	0	0	1	0	0	0	0	0	
Imp 12	08/15/90	11:59	lower	5	3	NA	25	0	0	0	56	10	0	1	0	0	0	
Imp 12	08/15/90	10:58	uppe	1	8	NA	278	0	0	0	227	50	0	0	0	0	0	
Imp 12	08/15/90	11:17	uppe	2	7	NA	80	0	0	0	78	20	0	0	0	0	0	
Imp 12	08/15/90	10:49	uppe	3	4	NA	97	0	0	0	202	20	0	0	0	0	0	
Imp 12	08/15/90	11:08	uppe	4	9	NA	126	1	0	0	117	40	1	1	0	0	0	
Imp 12	08/15/90	11:26	uppe	5	4	NA	233	0	0	0	112	50	0	0	0	0	0	
Imp 12	08/16/90	11:21	lower	1	1	NA	29	210	0	0	87	5	40	18	0	0	0	
Imp 12	08/16/90	11:02	lower	2	7	NA	160	70	0	0	160	30	8	31	0	3	0	too many to record
Imp 12	08/16/90	11:30	lower	3	6	NA	4	2	0	0	143	20	0	33	0	1	0	poor vis
Imp 12	08/16/90	11:12	lower	4	4	NA	8	0	0	0	43	NA	0	38	0	0	0	poor vis
Imp 12	08/16/90	10:52	lower	5	8	NA	3	0	0	0	1	NA	0	4	0	0	0	
Imp 12	08/16/90	12:17	uppe	1	1	NA	400	0	0	0	177	50	0	22	0	0	0	
Imp 12	08/16/90	12:09	uppe	2	4	NA	65	0	0	0	9	NA	0	0	0	2	0	
Imp 12	08/16/90	11:47	uppe	3	6	NA	79	0	0	0	55	30	0	0	0	0	0	
Imp 12	08/16/90	12:25	uppe	4	1	NA	188	0	0	0	170	30	0	0	0	0	0	
Imp 12	08/16/90	11:59	uppe	5	1	NA	50	0	0	0	14	NA	0	0	0	0	0	
Imp 12	08/21/90	11:32	lower	1	6	NA	179	41	0	0	179	40	0	0	0	1	0	
Imp 12	08/21/90	11:56	lower	2	6	NA	49	31	0	0	84	10	0	3	0	0	0	poor vis .
Imp 12	08/21/90	11:41	lower	3	8	NA	0	0	0	0	44	0	0	2	0	3	0	poor vis
Imp 12	08/21/90	11:23	lower	4	4	NA	2	0	0	0	13	0	0	4	1	1	0	poor vis
Imp 12	08/21/90	11:49	lower	5	5	NA	1	0	0	0	18	0	0	0	0	0	0	
Imp 12	08/21/90	10:33	uppe	1	9	NA	43	0	0	0	0	30	0	0	0	0	0	
Imp 12	08/21/90	10:58	uppe	2	1	NA	270	0	0	0	203	60	0	0	0	0	0	
Imp 12	08/21/90	10:50	uppe	3	9	NA	32	11	0	0	99	10	1	0	0	0	0	
Imp 12	08/21/90	10:41	uppe	4	3	NA	26	0	0	0	56	0	0	0	0	0	0	
Imp 12	08/21/90	11:08	uppe	5	6	NA	248	0	0	0	269	60	0	0	0	0	0	
Imp 12	08/23/90	13:17	lower	1	3	NA	168	42	0	0	129	20	3	0	0	0	0	poor vis
Imp 12	08/23/90	13:34	lower	2	9	NA	21	3	1	0	54	10	0	2	0	0	0	possible mating
Imp 12	08/23/90	13:41	lower	3	9	NA	29	0	0	0	62	10	0	4	0	1	0	
Imp 12	08/23/90	13:26	lower	4	9	NA	1	0	0	0	1	0	0	0	0	0	0	
Imp 12	08/23/90	13:08	lower	5	7	NA	458	14	0	0	292	80	0	1	0	1	0	too many for accurate count
Imp 12	08/23/90	12:20	uppe	1	9	NA	32	0	0	0	8	20	0	0	0	0	0	
Imp 12	08/23/90	12:36	uppe	2	3	NA	112	39	0	0	76	30	4	0	0	0	0	unclear boundries for territories
Imp 12	08/23/90	12:28	uppe	3	6	NA	241	0	0	0	49	60	0	0	0	0	0	
Imp 12	08/23/90	12:44	uppe	4	4	NA	217	0	0	0	108	60	0	1	0	0	0	
Imp 12	08/23/90	12:54	uppe	5	1	NA	94	41	0	0	79	20	0	0	0	0	0	no visible territories
Imp 12	08/24/90	10:46	lower	1	5	NA	425	0	0	0	253	100	0	15	0	0	0	
Imp 12	08/24/90	10:37	lower	2	1	NA	131	114	0	0	190	20	8	0	0	0	0	
Imp 12	08/24/90	10:11	lower	3	1	NA	392	0	0	0	299	60	0	0	0	0	0	poor vis
Imp 12	08/24/90	10:19	lower	4	1	NA	153	11	0	0	86	30	0	1	0	5	0	
Imp 12	08/24/90	10:28	lower	5	6	NA	299	0	0	0	198	40	0	0	0	0	0	
Imp 12	08/24/90	11:34	uppe	1	2	NA	311	0	0	0	193	40	0	5	0	0	0	
Imp 12	08/24/90	11:01	uppe	2	9	NA	68	0	0	0	17	30	0	2	0	2	0	
Imp 12	08/24/90	11:26	uppe	3	3	NA	86	13	0	0	223	30	3	3	0	2	0	
Imp 12	08/24/90	11:18	uppe	4	9	NA	13	0	0	0	6	NA	0	2	0	0	0	
Imp 12	08/24/90	11:10	uppe	5	9	NA	4	0	0	0	23	NA	0	1	0	3	0	poor vis/foam

TABLE 1 Continued

local	date	time	tran	qua	su	depth	cyp							gam		poe		comments
							cr	de	mate	fd	fl	no	ter	cr	fd	cr	fd	
Imp 12	08/27/90	10:51	lower	1	1	NA	27	113	0	0	248	0	8	78	0	2	0	
Imp 12	08/27/90	11:23	lower	2	3	NA	42	0	0	0	22	10	0	1	0	1	0	poor vis
Imp 12	08/27/90	10:59	lower	3	9	NA	48	0	0	0	259	20	0	90	0	0	0	
Imp 12	08/27/90	11:15	lower	4	3	NA	91	138	0	0	316	20	0	28	0	0	0	
Imp 12	08/27/90	11:08	lower	5	6	NA	83	183	0	0	3	10	4	3	0	0	0	
Imp 12	08/27/90	10:27	uppe	1	6	NA	388	0	0	0	351	40	0	3	0	0	0	
Imp 12	08/27/90	10:01	uppe	2	5	NA	196	63	0	0	118	30	1	0	0	0	0	
Imp 12	08/27/90	10:19	uppe	3	3	NA	128	174	0	0	103	30	15	0	0	0	0	
Imp 12	08/27/90	10:35	uppe	4	9	NA	182	138	0	0	264	30	0	0	0	0	0	overlap of territories
Imp 12	08/27/90	10:10	uppe	5	6	NA	198	132	0	0	214	30	7	0	0	0	0	
Imp 12	09/06/90	10:32	lower	1	7	NA	48	315	0	0	260	10	15	7	0	0	0	very poor vis
Imp 12	09/06/90	10:05	lower	2	3	NA	373	129	0	0	292	40	0	8	0	0	0	poor vis
Imp 12	09/06/90	10:22	lower	3	7	NA	118	4	0	80	303	20	3	8	0	20	0	
Imp 12	09/06/90	10:14	lower	4	8	NA	427	161	0	0	279	80	30	0	0	0	0	clear
Imp 12	09/06/90	10:41	lower	5	3	NA	3	185	0	175	395	355	0	13	0	0	0	defended and undefended terr's
Imp 12	09/06/90	11:14	uppe	1	5	NA	108	0	0	0	235	40	0	9	0	0	0	
Imp 12	09/06/90	10:56	uppe	2	1	NA	303	151	0	0	370	NA	3	0	0	0	0	
Imp 12	09/06/90	11:22	uppe	3	8	NA	333	22	0	0	355	50	1	13	0	0	0	
Imp 12	09/06/90	11:05	uppe	4	4	NA	127	0	0	0	209	50	0	13	0	0	0	
Imp 12	09/06/90	11:31	uppe	5	8	NA	58	190	0	0	0	NA	2	0	0	1	0	
Imp 12	09/13/90	12:37	lower	1	4	NA	473	0	0	260	155	100	0	0	0	0	0	2 live uca/no schooling/males excavating terr's
Imp 12	09/13/90	13:02	lower	2	5	NA	340	0	0	410	125	60	0	0	0	0	0	
Imp 12	09/13/90	13:22	lower	3	8	NA	1735	0	0	0	105	1000	0	0	0	0	0	
Imp 12	09/13/90	12:50	lower	4	2	NA	160	190	0	330	120	NA	0	0	0	0	0	poor vis
Imp 12	09/13/90	13:12	lower	5	4	NA	330	0	0	195	250	60	0	0	0	0	0	
Imp 12	09/13/90	14:14	uppe	1	4	NA	540	80	0	79	130	150	4	0	0	0	0	very loose schools
Imp 12	09/13/90	13:58	uppe	2	3	NA	215	275	0	90	105	30	14	0	0	0	0	excavation by flashing
Imp 12	09/13/90	14:06	uppe	3	8	NA	155	0	0	0	48	40	12	42	0	0	0	
Imp 12	09/13/90	13:39	uppe	4	3	NA	130	215	0	27	105	NA	21	22	0	0	0	
Imp 12	09/13/90	13:48	uppe	5	9	NA	205	215	0	3	190	10	26	7	0	0	0	no territorial boundries
Imp 12	09/14/90	16:38	lower	1	1	NA	80	330	0	335	65	20	6	0	0	0	0	map of terr belt on datasheet
Imp 12	09/14/90	16:03	lower	2	4	NA	1000	480	0	345	185	1000	20	0	0	0	0	feeding in undefended terr's
Imp 12	09/14/90	16:12	lower	3	8	10	450	0	0	120	330	100	0	0	0	0	0	too deep for terr's/10 inches
Imp 12	09/14/90	16:30	lower	4	4	NA	325	0	0	95	320	60	0	0	0	0	0	excavation by flashing
Imp 12	09/14/90	16:22	lower	5	9	NA	79	20	0	0	0	NA	0	0	0	0	0	
Imp 12	09/14/90	15:20	uppe	1	2	5	1000	0		1000	1000	1000	0	100	0	0	0	
Imp 12	09/14/90	15:49	uppe	2	3	NA	910	100	0	415	260	500	2	0	0	0	0	
Imp 12	09/14/90	15:40	uppe	3	7	NA	405	200	0	60	0	20	3	0	0	0	0	
Imp 12	09/14/90	15:31	uppe	4	9	NA	315	225	0	150	0	NA	0	0	0	0	0	
Imp 12	09/14/90	15:09	uppe	5	5	NA	225	215	0	160	0	20	6	0	0	0	0	females feeding in defended terr's
Imp 12	09/17/90	14:30	lower	1	7	NA	150	235	0	320	135	30	25	9	0	0	0	
Imp 12	09/17/90	14:11	lower	2	9	NA	275	300	0	155	190	60	20	0	0	0	0	poor vis
Imp 12	09/17/90	14:38	lower	3	5	12	132	0	0	13	275	10	0	40	0	0	0	poor vis and deep/12 inches
Imp 12	09/17/90	13:57	lower	4	2	NA	85	88	0	25	320	30	0	30	0	2	0	poor vis
Imp 12	09/17/90	14:20	lower	5	4	NA	165	300	0	155	190	10	4	0	0	0	0	excavation by flashing
Imp 12	09/17/90	15:49	uppe	1	4	NA	1000	0	0	545	110	1000	0	0	0	0	0	
Imp 12	09/17/90	15:41	uppe	2	6	NA	305	2	0	275	129	50	0	1	0	0	0	
Imp 12	09/17/90	15:57	uppe	3	5	NA	360	17	0	245	80	30	0	0	0	0	0	
Imp 12	09/17/90	15:33	uppe	4	5	NA	315	155	0	410	89	60	0	0	0	0	0	
Imp 12	09/17/90	15:26	uppe	5	1	NA	196	395	0	185	18	30	0	12	0	0	0	

TABLE 1 Continued

							cyp							gam		poe		
local	date	time	tran	qua	su	depth	cr	de	mate	fd	fl	no	ter	cr	fd	cr	fd	comments
Imp 12	09/19/90	12:24	lower	1	9	NA	12	0	0	0	159	5	0	21	4	0	0	
Imp 12	09/19/90	12:33	lower	2	4	NA	3	0	0	0	68	NA	12	23	3	1	0	
Imp 12	09/19/90	12:08	lower	3	9	NA	1	0	0	0	67	NA	0	0	0	0	0	
Imp 12	09/19/90	12:16	lower	4	6	NA	0	0	0	0	28	0	0	29	3	0	0	
Imp 12	09/19/90	12:00	lower	5	9	NA	2	0	0	0	0	NA	0	68	14	1	0	1 live uca climbing mangrove
Imp 12	09/19/90	12:48	uppe	1	2	NA	210	0	0	0	188	50	0	8	0	0	0	
Imp 12	09/19/90	13:07	uppe	2	8	NA	99	3	0	0	313	5	1	1	0	0	0	
Imp 12	09/19/90	13:16	uppe	3	4	NA	63	21	0	0	280	NA	2	0	0	0	0	
Imp 12	09/19/90	13:25	uppe	4	6	NA	83	11	0	4	240	10	1	0	0	0	0	
Imp 12	09/19/90	12:58	uppe	5	2	NA	206	6	0	0	185	30	1	2	0	0	0	
Imp 12	09/25/90	14:40	lower	1	3	3	1000	0	0	70	130	1000	0	85	20	0	0	
Imp 12	09/25/90	15:08	lower	2	8	4	447	90	1	0	58	70	5	17	0	0	0	several defenders for same terr/temporary with schools
Imp 12	09/25/90	14:31	lower	3	4	5	128	0	0	0	180	50	0	12	4	0	0	
Imp 12	09/25/90	15:00	lower	4	6	2	4	0	0	3	1	NA	0	49	12	0	0	
Imp 12	09/25/90	14:52	lower	5	5	3	43	0	0	0	143	20	0	3	0	0	0	feeding on terr remains
Imp 12	09/25/90	15:46	uppe	1	7	3	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	09/25/90	15:38	uppe	2	9	3	2	0	0	0	0	NA	0	0	0	0	0	floating detritus and foam
Imp 12	09/25/90	15:53	uppe	3	1	3	27	0	0	0	0	NA	0	6	0	0	0	
Imp 12	09/25/90	15:30	uppe	4	8	2	13	0	0	0	0	NA	0	3	0	0	0	
Imp 12	09/25/90	15:22	uppe	5	4	2	107	0	0	7	0	NA	0	110	12	0	0	
Imp 12	09/26/90	13:25	lower	1	1	1	247	0	0	2	0	20	0	0	0	0	0	
Imp 12	09/26/90	13:17	lower	2	9	1	188	0	0	14	0	20	0	1	0	0	0	
Imp 12	09/26/90	13:09	lower	3	8	1	278	0	0	0	0	60	0	0	0	0	0	undefended terr's
Imp 12	09/26/90	13:01	lower	4	4	2	2500	0	0	0	0	1000	0	9	0	0	0	
Imp 12	09/26/90	13:07	lower	5	6	0						-1						dry
Imp 12	09/26/90	13:41	uppe	1	7	0						-1						dry
Imp 12	09/26/90	13:42	uppe	2	4	0						-1						dry
Imp 12	09/26/90	13:43	uppe	3	7	0						-1						dry
Imp 12	09/26/90	13:45	uppe	4	6	0.5	20	0	0	0	0	0	0	0	0	0	0	fish in puddles
Imp 12	09/26/90	13:44	uppe	5	9	0						-1						dry
Imp 12	10/02/90	11:50	lower	1	7	4	425	0	0	380	305	100	0	40	0	0	0	new map of belt since colverts opened/shift to deeper
Imp 12	10/02/90	11:59	lower	2	8	4	432	0	0	460	270	50	0	15	7	0	0	no defending
Imp 12	10/02/90	12:28	lower	3	2	5	217	0	0	0	281	40	0	0	0	0	0	no defending
Imp 12	10/02/90	12:08	lower	4	7	5	495	0	0	430	255	90	0	13	0	62	0	poor vis
Imp 12	10/02/90	12:17	lower	5	8	2	40	0	0	0	0	20	0	130	0	0	0	
Imp 12	10/02/90	13:07	uppe	1	8	3	0	0	0	0	0	0	0	0	0	0	0	
Imp 12	10/02/90	12:53	uppe	2	6	3	0	0	0	0	0	0	0	2	0	0	0	
Imp 12	10/02/90	13:00	uppe	3	3	3	4	0	0	0	1	NA	0	0	0	0	0	
Imp 12	10/02/90	13:14	uppe	4	5	4	464	185	0	345	72	60	0	0	0	0	0	
Imp 12	10/02/90	12:44	uppe	5	7	3	11	0	0	0	0	5	0	11	0	0	0	
Imp 12	10/15/90	13:02	lower	1	5	5	380	0	0	37	250	50	0	2	0	1	0	caseopia jellyfish 8 inches in diameter
Imp 12	10/15/90	13:11	lower	2	3	3	120	0	0	0	322	20	0	7	0	0	0	
Imp 12	10/15/90	13:27	lower	3	7	4	8	0	0	0	65	NA	0	6	0	1	0	poor vis
Imp 12	10/15/90	13:19	lower	4	7	3.5	150	0	0	0	55	30	0	7	0	0	0	
Imp 12	10/15/90	13:34	lower	5	4	4	261	0	0	0	298	50	0	22	0	0	0	
Imp 12	10/15/90	12:44	uppe	1	4	4	65	0	0	3	260	20	0	188	0	0	0	
Imp 12	10/15/90	12:21	uppe	2	1	3	62	0	0	43	249	NA	0	0	0	0	0	
Imp 12	10/15/90	12:37	uppe	3	8	4	106	0	0	23	220	10	0	0	0	0	0	
Imp 12	10/15/90	12:29	uppe	4	5	4	270	0	0	450	298	60	0	0	0	0	0	algal feeding area
Imp 12	10/15/90	12:13	uppe	5	7	3	170	0	0	50	231	20	0	11	0	0	0	

TABLE 1 Continued

							cyp							gam		poe		
local	date	time	tran	qua	su	depth	cr	de	mate	fd	fl	no	ter	cr	fd	cr	fd	comments
Imp 12	10/23/90	13:52	lower	1	2	NA	558	0	0	0	52	50	0	0	0	0	0	
Imp 12	10/23/90	13:32	lower	2	1	NA	167	0	0	0	0	40	0	0	0	0	0	
Imp 12	10/23/90	13:44	lower	3	1	NA	1128	0	0	0	448	100	0	0	0	0	0	
Imp 12	10/23/90	13:22	lower	4	9	0						-1						dry
Imp 12	10/23/90	13:23	lower	5	5	NA	517	0	0	3	48	80	0	0	0	0	0	
Imp 12	10/23/90	14:14	uppe	1	2	NA	396	0	0	260	330	60	0	0	0	0	0	
Imp 12	10/23/90	14:23	uppe	2	1	NA	140	0	0	0	3	NA	0	0	0	0	0	
Imp 12	10/23/90	14:30	uppe	3	2	0						-1						dry
Imp 12	10/23/90	14:31	uppe	4	7	NA	280	0	0	0	0	NA	0	0	0	0	0	
Imp 12	10/23/90	14:37	uppe	5	3	0						-1						dry
Imp 12	10/25/90	16:08	lower	1	8	2	11	0	0	2	0	NA	0	0	0	0	0	poor vis
Imp 12	10/25/90	16:01	lower	2	6	2	67	0	0	0	0	NA	0	0	0	0	0	
Imp 12	10/25/90	16:15	lower	3	5	4	468	0	0	85	570	200	0	1	0	0	0	
Imp 12	10/25/90	16:23	lower	4	8	2	36	0	0	0	0	NA	0	0	0	0	0	
Imp 12	10/25/90	16:29	lower	5	9	0						-1						dry
Imp 12	10/25/90	15:42	uppe	1	6	1	0	0	0	0	0	0	0	0	0	0	0	poor vis
Imp 12	10/25/90	15:49	uppe	2	3	1	54	0	0	8	6	NA	0	0	0	0	0	
Imp 12	10/25/90	15:34	uppe	3	2	1	175	0	0	19	16	NA	0	0	0	0	0	
Imp 12	10/25/90	15:25	uppe	4	3	1	591	0	0	4	241	100	0	0	0	0	0	
Imp 12	10/25/90	15:31	uppe	5	8	0						-1						dry
Imp 12	10/31/90	10:36	lower	1	6	6	173	2	0	40	0	30	0	0	0	0	0	
Imp 12	10/31/90	10:43	lower	2	7	7	229	108	0	0	182	30	12	1	0	0	0	
Imp 12	10/31/90	11:00	lower	3	8	6	17	0	0	0	17	NA	0	0	0	0	0	poor vis
Imp 12	10/31/90	10:52	lower	4	4	4	171	0	0	7	130	10	0	0	0	0	0	
Imp 12	10/31/90	10:26	lower	5	3	6	358	25	0	80	280	90	0	0	0	0	0	excavation by flashing
Imp 12	10/31/90	11:31	uppe	1	1	5	208	0	0	0	75	50	0	0	0	0	0	
Imp 12	10/31/90	11:47	uppe	2	9	5	270	0	0	0	385	40	0	0	0	0	0	
Imp 12	10/31/90	11:13	uppe	3	1	5	17	0	0	9	47	NA	0	0	0	0	0	
Imp 12	10/31/90	11:39	uppe	4	1	4	225	0	0	17	205	100	0	0	0	0	0	
Imp 12	10/31/90	11:22	uppe	5	8	4	205	0	0	0	234	30	0	1	0	0	0	
Imp 12	11/07/90	16:11	lower	1	5	4	60	0	0	0	28	10	0	12	0	1	0	poor vis
Imp 12	11/07/90	16:18	lower	2	9	5	80	0	0	0	50	NA	0	3	0	0	0	
Imp 12	11/07/90	16:39	lower	3	7	7	0	0	0	0	0	0	0	1	0	0	0	very poor vis
Imp 12	11/07/90	16:25	lower	4	8	4	180	12	0	0	375	NA	0	8	0	0	0	
Imp 12	11/07/90	16:32	lower	5	2	4	135	0	0	0	255	20	0	0	0	0	0	
Imp 12	11/07/90	15:59	uppe	1	3	NA	625	40	0	0	450	150	0	300	0	4	0	
Imp 12	11/07/90	15:37	uppe	2	9	NA	295	0	0	195	295	40	0	0	0	0	0	
Imp 12	11/07/90	15:29	uppe	3	1	NA	330	135	0	395	180	30	1	30	0	0	0	
Imp 12	11/07/90	15:44	uppe	4	1	NA	248	80	0	430	160	60	1	7	0	0	0	
Imp 12	11/07/90	15:51	uppe	5	8	NA	275	0	0	410	270	40	0	15	0	0	0	
Imp 12	11/15/90	13:05	lower	1	2	4	0	0	0	0	145	0	0	0	0	0	0	poor vis
Imp 12	11/15/90	12:35	lower	2	1	5	0	0	0	0	0	0	0	0	0	0	0	zero vis
Imp 12	11/15/90	12:42	lower	3	6	4.5	9	0	0	0	120	NA	0	0	0	0	0	
Imp 12	11/15/90	12:50	lower	4	6	2	157	0	0	75	15	40	0	0	0	0	0	
Imp 12	11/15/90	12:57	lower	5	9	2	73	0	0	0	3	10	0	0	0	0	0	
Imp 12	11/15/90	12:00	uppe	1	2	2.5	110	0	0	0	113	10	0	0	0	0	0	
Imp 12	11/15/90	12:23	uppe	2	9	2	30	0	0	40	109	5	0	0	0	0	0	
Imp 12	11/15/90	12:16	uppe	3	1	3	185	8	0	80	150	20	0	0	0	0	0	defend area of several territories/whole subplot
Imp 12	11/15/90	11:52	uppe	4	5	3	167	0	0	95	68	20	0	0	0	0	0	
Imp 12	11/15/90	12:08	uppe	5	3	2	52	0	0	0	120	10	0	0	0	0	0	poor vis

TABLE 2. Blue Hole Point Cyprinodon observations. Local = study site, tran = transect, quad = quadrat, su = section 1-9 within each quadrat, depth = water depth in the section in inches, cyp = Cyprinodon behavior observations which include; *cr = cruising, de = defending, mate = mating,* no = number estimate for minimum density in each section, ter = number of observed territories established. Gam and Poe = Gambusia and Poecilia behaviors.

							cyp							gam		poe		
local	date	time	tran	qua	su	depth	cr	de	mate	fd	fl	no	ter	cr	fd	cr	fd	comments
Bl Hl Pt	09/13/90	15:10	lower	1	5	0						-1						dry
Bl Hl Pt	09/13/90	15:07	lower	2	2	0						-1						dry
Bl Hl Pt	09/13/90	15:01	lower	3	2	0.5	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	09/13/90	15:09	lower	4	4	0						-1						dry
Bl Hl Pt	09/13/90	15:08	lower	5	4	0						-1						dry
Bl Hl Pt	09/13/90	15:11	uppe	1	6	0						-1						dry
Bl Hl Pt	09/13/90	15:13	uppe	2	9	0						-1						dry
Bl Hl Pt	09/13/90	15:12	uppe	3	3	0						-1						dry
Bl Hl Pt	09/13/90	15:15	uppe	4	8	0						-1						dry
Bl Hl Pt	09/13/90	15:14	uppe	5	7	0						-1						berm
Bl Hl Pt	09/17/90	12:54	lower	1	5	NA	208	0	0	2	3	NA	0	0	0	2	0	1 uca
Bl Hl Pt	09/17/90	12:47	lower	2	7	NA	395	0	0	190	85	40	0	0	0	0	0	
Bl Hl Pt	09/17/90	12:39	lower	3	6	NA	280	0	0	106	100	30	0	1	0	0	0	
Bl Hl Pt	09/17/90	12:30	lower	4	1	NA	313	0	0	125	0	20	0	0	0	0	0	
Bl Hl Pt	09/17/90	13:00	lower	5	7	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	09/17/90	12:22	uppe	1	1	3	365	0	0	270	0	50	0	1	0	0	0	
Bl Hl Pt	09/17/90	12:01	uppe	2	6	2	18	0	0	3	0	NA	0	0	0	0	0	
Bl Hl Pt	09/17/90	12:08	uppe	3	8	0						-1						
Bl Hl Pt	09/17/90	12:14	uppe	4	8	0						-1						dry
Bl Hl Pt	09/17/90	12:15	uppe	5	1	0						-1						berm
Bl Hl Pt	09/18/90	11:19	lower	1	9	NA	0	0	0	0	0	0	0	0	0	0	0	1 live uca
Bl Hl Pt	09/18/90	11:02	lower	2	3	NA	1	0	0	0	0	1	0	0	0	0	0	
Bl Hl Pt	09/18/90	11:27	lower	3	2	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	09/18/90	11:11	lower	4	4	NA	0	0	0	0	0	0	0	0	0	0	0	2 live uca
Bl Hl Pt	09/18/90	10:54	lower	5	4	NA	1	0	0	0	0	1	0	0	0	0	0	
Bl Hl Pt	09/18/90	10:38	uppe	1	6	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	09/18/90	10:31	uppe	2	2	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	09/18/90	10:46	uppe	3	5	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	09/18/90	10:28	uppe	4	6	0						-1						dry
Bl Hl Pt	09/18/90	10:51	uppe	5	1	0						-1						berm
Bl Hl Pt	09/25/90	15:05	lower	1	8	5	3	0	0	0	0	3	0	2	0	2	0	
Bl Hl Pt	09/25/90	14:55	lower	2	5	4	1	0	0	0	4	1	0	2	0	0	0	
Bl Hl Pt	09/25/90	15:27	lower	3	3	5	1	0	0	0	0	1	0	2	0	0	0	
Bl Hl Pt	09/25/90	15:13	lower	4	7	4	7	0	0	0	5	NA	0	1	0	0	0	
Bl Hl Pt	09/25/90	15:20	lower	5	3	4	2	0	0	0	0	2	0	1	0	0	0	
Bl Hl Pt	09/25/90	14:40	uppe	1	4	2	0	0	0	0	4	4	0	0	0	0	0	
Bl Hl Pt	09/25/90	14:48	uppe	2	3	2	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	09/25/90	14:49	uppe	3	5	0						-1						dry
Bl Hl Pt	09/25/90	14:50	uppe	4	1	0						-1						dry
Bl Hl Pt	09/25/90	14:46	uppe	5	1	0						-1						berm
Bl Hl Pt	10/02/90	10:20	lower	1	9	5	1	0	0	0	0	1	0	17	9	0	0	
Bl Hl Pt	10/02/90	10:36	lower	2	2	5	200	92	0	0	0	NA	6	22	0	0	0	6 very large males >60 mm
Bl Hl Pt	10/02/90	10:28	lower	3	9	5	98	0	0	62	0	20	0	2	0	1	0	
Bl Hl Pt	10/02/90	10:46	lower	4	2	5	175	0	0	38	0	NA	0	16	0	0	0	
Bl Hl Pt	10/02/90	10:11	lower	5	6	4	19	0	0	0	0	NA	0	4	0	0	0	
Bl Hl Pt	10/02/90	11:11	uppe	1	8	3	4	0	0	0	0	NA	0	1	0	0	0	
Bl Hl Pt	10/02/90	10:55	uppe	2	8	2	65	0	0	141	3	10	0	0	0	0	0	
Bl Hl Pt	10/02/90	11:03	uppe	3	8	1	29	0	0	0	0	NA	0	0	0	0	0	
Bl Hl Pt	10/02/90	10:54	uppe	4	2	0						-1						dry
Bl Hl Pt	10/02/90	11:02	uppe	5	9	0						-1						berm

TABLE 2 Continued

local	date	time	tran	qua	su	depth	cyp cr	cyp de	cyp mate	cyp fd	cyp fl	cyp no	cyp ter	gam cr	gam fd	poe cr	poe fd	comments
Bl Hl Pt	10/15/90	10:40	lower	1	8	5	8	0	0	0	0	NA	0	8	0	0	0	poor vis
Bl Hl Pt	10/15/90	10:48	lower	2	9	4	12	0	0	0	2	NA	0	11	0	0	0	
Bl Hl Pt	10/15/90	10:32	lower	3	4	4	116	0	0	18	0	10	0	3	0	0	0	
Bl Hl Pt	10/15/90	10:17	lower	4	6	4	0	0	0	0	0	0	0	24	0	0	0	
Bl Hl Pt	10/15/90	10:24	lower	5	6	3	0	0	0	0	0	0	0	32	0	0	0	
Bl Hl Pt	10/15/90	10:08	uppe	1	6	3	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	10/15/90	09:59	uppe	2	7	2	6	0	0	0	0	NA	0	0	0	0	0	
Bl Hl Pt	10/15/90	09:52	uppe	3	4	1	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	10/15/90	09:51	uppe	4	7	0						-1						dry
Bl Hl Pt	10/15/90	10:14	uppe	5	5	0						-1						berm
Bl Hl Pt	10/23/90	15:29	lower	1	6	3	0	0	0	0	0	0	0	0	0	0	0	zero vis/100% mangrove growth
Bl Hl Pt	10/23/90	15:14	lower	2	8	2	295	0	0	235	35	30	0	7	0	0	0	
Bl Hl Pt	10/23/90	15:07	lower	3	1	2	43	0	0	0	0	10	0	0	0	0	0	
Bl Hl Pt	10/23/90	15:21	lower	4	9	1	9	0	0	0	0	0	0	38	0	0	0	
Bl Hl Pt	10/23/90	15:30	lower	5	1	1	158	0	0	0	0	0	0	7	0	0	0	
Bl Hl Pt	10/23/90	14:59	uppe	1	9	0.5	143	0	0	35	2	5	0	0	0	0	0	
Bl Hl Pt	10/23/90	15:05	uppe	2	1	0						-1						dry
Bl Hl Pt	10/23/90	15:05	uppe	3	8	0						-1						berm
Bl Hl Pt	10/23/90	15:06	uppe	4	5	0						-1						dry
Bl Hl Pt	10/23/90	15:06	uppe	5	1	0						-1						dry
Bl Hl Pt	10/31/90	12:50	lower	1	9	4	4	0	0	0	0	4	0	19	0	0	0	
Bl Hl Pt	10/31/90	12:58	lower	2	6	3	4	0	0	0	0	4	0	6	0	0	0	
Bl Hl Pt	10/31/90	13:12	lower	3	3	4	0	0	0	0	0	0	0	7	0	0	0	
Bl Hl Pt	10/31/90	12:43	lower	4	3	4	21	0	0	0	0	NA	0	0	0	0	0	
Bl Hl Pt	10/31/90	13:05	lower	5	2	2	7	0	0	0	0	NA	0	38	0	0	0	
Bl Hl Pt	10/31/90	12:21	uppe	1	4	3	14	0	0	1	0	NA	0	0	0	0	0	
Bl Hl Pt	10/31/90	12:14	uppe	2	6	3	2	0	0	0	0	2	0	0	0	0	0	
Bl Hl Pt	10/31/90	12:28	uppe	3	1	1	36	0	0	0	0	30	0	0	0	0	0	
Bl Hl Pt	10/31/90	12:13	uppe	4	8	0						-1						dry
Bl Hl Pt	10/31/90	12:20	uppe	5	2	0						-1						berm
Bl Hl Pt	11/13/90	09:40	lower	1	9	NA	2	0	0	0	0	2	0	6	0	0	0	
Bl Hl Pt	11/13/90	09:57	lower	2	6	NA	2	0	0	0	0	2	0	0	0	0	0	
Bl Hl Pt	11/13/90	10:13	lower	3	3	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	11/13/90	09:48	lower	4	5	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	11/13/90	10:05	lower	5	3	NA	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	11/13/90	10:22	uppe	1	8	1	0	0	0	0	0	0	0	0	0	0	0	bobcat sighted on marsh upland/large animal!
Bl Hl Pt	11/13/90	10:29	uppe	2	4	1	0	0	0	0	0	0	0	0	0	0	0	
Bl Hl Pt	11/13/90	10:36	uppe	3	9	0						-1						dry
Bl Hl Pt	11/13/90	10:20	uppe	4	7	0						-1						dry
Bl Hl Pt	11/13/90	10:35	uppe	5	3	0						-1						berm

TABLE 3. Grand Harbor Cyprinodon observations. Local = study site, tran = transect, quad = quadrat, su = section 1-9 within each quadrat, depth = water depth in the section in inches, cyp = Cyprinodon behavior observations which include; cr = cruising, de = defending, mate = mating, no = number estimate for minimum density in each section, ter = number of observed territories established. Gam and Poe = Gambusia and Poecilia behaviors.

							cyp							gam		poe		
local	date	time	tran	qua	su	depth	cr	de	mate	fd	fl	no	ter	cr	fd	cr	fd	comments
Grand H	10/04/90	13:47	lower	1	7	2	0	0	0	0	0	0	0	30	0	0	0	1 live uca
Grand H	10/04/90	13:34	lower	2	6	2	0	0	0	0	0	0	0	98	0	0	0	
Grand H	10/04/90	13:41	lower	3	3	3	0	0	0	0	0	0	0	52	0	0	0	floating mat
Grand H	10/04/90	13:54	lower	4	6	2	0	0	0	0	0	0	0	157	0	0	0	floating mat
Grand H	10/04/90	13:25	lower	5	1	3	0	0	0	0	0	0	0	94	0	0	0	floating mat
Grand H	10/04/90	13:08	uppe	1	3	3	0	0	0	0	0	0	0	89	0	0	0	floating mat/activity underneath
Grand H	10/04/90	13:17	uppe	2	4	2	0	0	0	0	0	0	0	205	0	0	0	
Grand H	10/04/90	12:56	uppe	3	9	0						-1						dry
Grand H	10/04/90	12:58	uppe	4	9	1	0	0	0	0	0	0	0	32	0	0	0	
Grand H	10/04/90	12:57	uppe	5	5	0						-1						berm
Grand H	10/18/90	12:34	lower	1	5	4	0	0	0	0	0	0	0	0	0	0	0	
Grand H	10/18/90	12:57	lower	2	7	3	200	0	0	0	150	30	0	0	0	56	0	
Grand H	10/18/90	12:42	lower	3	9	4	278	0	0	0	30	20	0	0	0	7	0	
Grand H	10/18/90	13:15	lower	4	7	NA	86	0	0	0	0	NA	0	0	0	43	0	
Grand H	10/18/90	13:08	lower	5	7	3	28	0	0	0	0	NA	0	0	0	13	0	
Grand H	10/18/90	13:31	uppe	1	2	3	142	0	0	22	45	30	0	2	0	32	0	
Grand H	10/18/90	13:39	uppe	2	3	2	88	0	0	0	0	10	0	0	0	17	0	
Grand H	10/18/90	13:45	uppe	3	4	1	16	0	0	0	4	NA	0	0	0	37	0	
Grand H	10/18/90	13:22	uppe	4	5	0.5	0	0	0	0	0	0	0	0	0	17	0	
Grand H	10/18/90	13:38	uppe	5	7	0						-1						berm
Grand H	11/02/90	13:01	lower	1	1	5	53	0	0	0	6	10	0	0	0	0	0	
Grand H	11/02/90	12:35	lower	2	3	6	9	0	0	0	0	NA	0	1	0	0	0	
Grand H	11/02/90	12:54	lower	3	8	4	8	0	0	0	0	NA	0	0	0	0	0	
Grand H	11/02/90	12:43	lower	4	4	5	135	25	0	120	30	20	0	0	0	0	0	agressive defending/biting/excavation then defend hole
Grand H	11/02/90	12:27	lower	5	5	5	132	0	0	8	114	20	0	0	0	0	0	
Grand H	11/02/90	12:06	uppe	1	3	4	0	0	0	0	0	0	0	0	0	0	0	
Grand H	11/02/90	12:13	uppe	2	8	6	6	0	0	0	0	NA	0	0	0	0	0	
Grand H	11/02/90	12:20	uppe	3	7	4	1	0	0	0	0	1	0	0	0	2	0	
Grand H	11/02/90	11:58	uppe	4	2	3	8	0	0	0	2	NA	0	1	0	0	0	
Grand H	11/02/90	12:12	uppe	5	1	0						-1						berm
Grand H	11/19/90	13:28	lower	1	6	6	2	0	0	0	0	2	0	0	0	0	0	
Grand H	11/19/90	13:20	lower	2	4	4	3	0	0	0	0	3	0	0	0	0	0	
Grand H	11/19/90	13:36	lower	3	8	5	5	0	0	0	0	4	0	0	0	0	0	
Grand H	11/19/90	13:12	lower	4	6	5	0	0	0	0	0	0	0	0	0	0	0	
Grand H	11/19/90	13:05	lower	5	6	5	8	0	0	0	0	NA	0	0	0	0	0	
Grand H	11/19/90	12:48	uppe	1	4	5	8	0	0	0	0	NA	0	0	0	0	0	
Grand H	11/19/90	12:40	uppe	2	2	6	37	8	0	1	0	10	1	0	0	0	0	male display
Grand H	11/19/90	12:32	uppe	3	7	3	0	0	0	0	0	0	0	2	0	0	0	
Grand H	11/19/90	12:56	uppe	4	8	2	0	0	0	0	0	0	0	1	0	0	0	
Grand H	11/19/90	12:31	uppe	5	3	0						-1						berm

TABLE 4. Impoundment 12 Uca data separated by transect and quadrat for each sampling date. Local = study site, Trans = transect, Quad = quadrat, Mean = mean of the three counts for each quadrat, Ave Mean = mean for all quadrats and all counts in the transect, Std Dev = standard deviation for all quadrats and all counts in the transect.

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Imp 12	Lower	12/29/89	0-5	6	3	5	4.67	9.25	13.29
Imp 12	Lower	12/29/89	5-10	1	0	0	0.33		
Imp 12	Lower	12/29/89	10-15	39	12	0	17.00		
Imp 12	Lower	12/29/89	15+	37	6	2	15.00		
Imp 12	Lower	01/16/90	0-5	30	8	8	15.33	9.50	9.95
Imp 12	Lower	01/16/90	5-10	3	0	1	1.33		
Imp 12	Lower	01/16/90	10-15	0	25	3	9.33		
Imp 12	Lower	01/16/90	15+	20	14	2	12.00		
Imp 12	Lower	02/21/90	0-5	14	0	8	7.33	5.92	8.26
Imp 12	Lower	02/21/90	5-10	0	3	4	2.33		
Imp 12	Lower	02/21/90	10-15	0	15	0	5.00		
Imp 12	Lower	02/21/90	15+	27	0	0	9.00		
Imp 12	Lower	03/28/90	0-5	8	0	2	3.33	3.42	4.50
Imp 12	Lower	03/28/90	5-10	0	0	0	0.00		
Imp 12	Lower	03/28/90	10-15	5	4	7	5.33		
Imp 12	Lower	03/28/90	15+	15	0	0	5.00		
Imp 12	Lower	04/26/90	0-5	5	8	6	6.33	5.75	6.35
Imp 12	Lower	04/26/90	5-10	0	4	0	1.33		
Imp 12	Lower	04/26/90	10-15	1	19	2	7.33		
Imp 12	Lower	04/26/90	15+	19	3	2	8.00		
Imp 12	Lower	05/21/90	0-5	18	3	2	7.67	6.50	5.14
Imp 12	Lower	05/21/90	5-10	1	4	7	4.00		
Imp 12	Lower	05/21/90	10-15	5	3	1	3.00		
Imp 12	Lower	05/21/90	15+	12	11	11	11.33		
Imp 12	Lower	06/22/90	0-5	0	0	0	0.00	0.00	0.00
Imp 12	Lower	06/22/90	5-10	0	0	0	0.00		
Imp 12	Lower	06/22/90	10-15	0	0	0	0.00		
Imp 12	Lower	06/22/90	15+	0	0	0	0.00		
Imp 12	Lower	07/24/90	0-5	0	0	0	0.00	0.00	0.00
Imp 12	Lower	07/24/90	5-10	0	0	0	0.00		
Imp 12	Lower	07/24/90	10-15	0	0	0	0.00		
Imp 12	Lower	07/24/90	15+	0	0	0	0.00		
Imp 12	Lower	08/17/90	0-5	0	0	0	0.00	0.00	0.00
Imp 12	Lower	08/17/90	5-10	0	0	0	0.00		
Imp 12	Lower	08/17/90	10-15	0	0	0	0.00		
Imp 12	Lower	08/17/90	15+	0	0	0	0.00		
Imp 12	Lower	09/20/90	0-5	0	0	0	0.00	0.00	0.00
Imp 12	Lower	09/20/90	5-10	0	0	0	0.00		
Imp 12	Lower	09/20/90	10-15	0	0	0	0.00		
Imp 12	Lower	09/20/90	15+	0	0	0	0.00		
Imp 12	Lower	10/18/90	0-5	0	0	0	0.00	0.00	0.00
Imp 12	Lower	10/18/90	5-10	0	0	0	0.00		
Imp 12	Lower	10/18/90	10-15	0	0	0	0.00		
Imp 12	Lower	10/18/90	15+	0	0	0	0.00		
Imp 12	Lower	11/19/90	0-5	0	0	0	0.00	0.00	0.00
Imp 12	Lower	11/19/90	5-10	0	0	0	0.00		
Imp 12	Lower	11/19/90	10-15	0	0	0	0.00		
Imp 12	Lower	11/19/90	15+	0	0	0	0.00		

TABLE 4. Continued

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Imp 12	Upper	12/29/89	0-5	0	0	1	0.33	10.50	11.34
Imp 12	Upper	12/29/89	5-10	2	2	5	3.00		
Imp 12	Upper	12/29/89	10-15	38	26	12	25.33		
Imp 12	Upper	12/29/89	15+	12	18	10	13.33		
Imp 12	Upper	01/16/90	0-5	0	1	0	0.33	8.75	7.43
Imp 12	Upper	01/16/90	5-10	2	3	5	3.33		
Imp 12	Upper	01/16/90	10-15	15	16	20	17.00		
Imp 12	Upper	01/16/90	15+	9	18	16	14.33		
Imp 12	Upper	02/21/90	0-5	0	0	4	1.33	9.33	7.21
Imp 12	Upper	02/21/90	5-10	2	5	3	3.33		
Imp 12	Upper	02/21/90	10-15	15	19	15	16.33		
Imp 12	Upper	02/21/90	15+	18	15	16	16.33		
Imp 12	Upper	03/28/90	0-5	0	3	3	2.00	9.00	5.96
Imp 12	Upper	03/28/90	5-10	4	9	5	6.00		
Imp 12	Upper	03/28/90	10-15	16	17	18	17.00		
Imp 12	Upper	03/28/90	15+	12	14	7	11.00		
Imp 12	Upper	04/26/90	0-5	3	0	1	1.33	7.42	5.60
Imp 12	Upper	04/26/90	5-10	4	5	2	3.67		
Imp 12	Upper	04/26/90	10-15	12	7	10	9.67		
Imp 12	Upper	04/26/90	15+	12	16	17	15.00		
Imp 12	Upper	05/21/90	0-5	0	2	5	2.33	8.83	5.96
Imp 12	Upper	05/21/90	5-10	5	4	4	4.33		
Imp 12	Upper	05/21/90	10-15	10	13	15	12.67		
Imp 12	Upper	05/21/90	15+	13	17	18	16.00		
Imp 12	Upper	06/22/90	0-5	0	8	0	2.67	8.50	6.60
Imp 12	Upper	06/22/90	5-10	4	5	1	3.33		
Imp 12	Upper	06/22/90	10-15	8	11	21	13.33		
Imp 12	Upper	06/22/90	15+	17	15	12	14.67		
Imp 12	Upper	07/24/90	0-5	0	0	0	0.00	6.25	8.22
Imp 12	Upper	07/24/90	5-10	0	0	0	0.00		
Imp 12	Upper	07/24/90	10-15	0	5	22	9.00		
Imp 12	Upper	07/24/90	15+	16	17	15	16.00		
Imp 12	Upper	08/17/90	0-5	0	0	0	0.00	6.58	10.77
Imp 12	Upper	08/17/90	5-10	0	0	0	0.00		
Imp 12	Upper	08/17/90	10-15	0	0	6	2.00		
Imp 12	Upper	08/17/90	15+	18	32	23	24.33		
Imp 12	Upper	09/20/90	0-5	0	0	0	0.00	2.83	6.20
Imp 12	Upper	09/20/90	5-10	0	0	0	0.00		
Imp 12	Upper	09/20/90	10-15	0	0	0	0.00		
Imp 12	Upper	09/20/90	15+	7	22	5	11.33		
Imp 12	Upper	10/18/90	0-5	0	0	0	0.00	0.67	1.43
Imp 12	Upper	10/18/90	5-10	0	0	0	0.00		
Imp 12	Upper	10/18/90	10-15	0	0	0	0.00		
Imp 12	Upper	10/18/90	15+	1	2	5	2.67		
Imp 12	Upper	11/19/90	0-5	0	0	0	0.00	4.17	5.10
Imp 12	Upper	11/19/90	5-10	0	0	0	0.00		
Imp 12	Upper	11/19/90	10-15	3	6	5	4.67		
Imp 12	Upper	11/19/90	15+	9	12	15	12.00		

TABLE 5. North Marsh Uca data separated by transect and quadrat for each sampling date. Local = study site, Trans = transect, Quad = quadrat, Mean = mean of the three counts for each quadrat, Ave Mean = mean for all quadrats and all counts in the transect, Std Dev = standard deviation for all quadrats and all counts in the transect.

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
North M	Lower	12/29/89	0-5	52	14	58	41.33	80.50	29.00
North M	Lower	12/29/89	5-10	120	80	108	102.67		
North M	Lower	12/29/89	10-15	111	81	97	96.33		
North M	Lower	12/29/89	15+	72	105	68	81.67		
North M	Lower	01/26/90	0-5	20	52	60	44.00	48.25	14.89
North M	Lower	01/26/90	5-10	30	63	71	54.67		
North M	Lower	01/26/90	10-15	62	56	49	55.67		
North M	Lower	01/26/90	15+	47	37	32	38.67		
North M	Lower	02/21/90	0-5	28	17	40	28.33	33.83	7.32
North M	Lower	02/21/90	5-10	33	44	32	36.33		
North M	Lower	02/21/90	10-15	40	44	35	39.67		
North M	Lower	02/21/90	15+	29	34	30	31.00		
North M	Lower	03/28/90	0-5	35	18	32	28.33	31.17	5.62
North M	Lower	03/28/90	5-10	36	38	32	35.33		
North M	Lower	03/28/90	10-15	37	34	32	34.33		
North M	Lower	03/28/90	15+	30	25	25	26.67		
North M	Lower	04/25/90	0-5	30	37	13	26.67	29.50	6.54
North M	Lower	04/25/90	5-10	30	24	26	26.67		
North M	Lower	04/25/90	10-15	33	38	31	34.00		
North M	Lower	04/25/90	15+	36	26	30	30.67		
North M	Lower	05/21/90	0-5	24	5	16	15.00	22.42	7.27
North M	Lower	05/21/90	5-10	36	27	28	30.33		
North M	Lower	05/21/90	10-15	24	20	18	20.67		
North M	Lower	05/21/90	15+	21	27	23	23.67		
North M	Lower	06/22/90	0-5	39	10	34	27.67	33.50	8.34
North M	Lower	06/22/90	5-10	42	44	38	41.33		
North M	Lower	06/22/90	10-15	32	32	30	31.33		
North M	Lower	06/22/90	15+	33	30	38	33.67		
North M	Lower	07/24/90	0-5	12	28	34	24.67	28.50	7.59
North M	Lower	07/24/90	5-10	20	32	36	29.33		
North M	Lower	07/24/90	10-15	24	24	30	26.00		
North M	Lower	07/24/90	15+	41	35	26	34.00		
North M	Lower	08/17/90	0-5	31	42	59	44.00	54.00	11.17
North M	Lower	08/17/90	5-10	64	62	60	62.00		
North M	Lower	08/17/90	10-15	42	55	64	53.67		
North M	Lower	08/17/90	15+	43	69	57	56.33		
North M	Lower	09/21/90	0-5	0	0	0	0.00	0.00	0.00
North M	Lower	09/21/90	5-10	0	0	0	0.00		
North M	Lower	09/21/90	10-15	0	0	0	0.00		
North M	Lower	09/21/90	15+	0	0	0	0.00		
North M	Lower	10/19/90	0-5	0	0	0	0.00	2.08	1.71
North M	Lower	10/19/90	5-10	3	2	2	2.33		
North M	Lower	10/19/90	10-15	2	1	4	2.33		
North M	Lower	10/19/90	15+	3	2	6	3.67		
North M	Lower	11/20/90	0-5	0	0	0	0.00	0.00	0.00
North M	Lower	11/20/90	5-10	0	0	0	0.00		
North M	Lower	11/20/90	10-15	0	0	0	0.00		
North M	Lower	11/20/90	15+	0	0	0	0.00		

TABLE 5. Continued

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
North M	Upper	12/29/89	0-5	34	40	41	38.33	45.00	26.83
North M	Upper	12/29/89	5-10	50	50	66	55.33		
North M	Upper	12/29/89	10-15	71	89	77	79.00		
North M	Upper	12/29/89	15+	15	5	2	7.33		
North M	Upper	01/26/90	0-5	30	54	44	42.67	35.42	13.30
North M	Upper	01/26/90	5-10	26	40	40	35.33		
North M	Upper	01/26/90	10-15	47	49	44	46.67		
North M	Upper	01/26/90	15+	24	8	19	17.00		
North M	Upper	02/21/90	0-5	29	28	32	29.67	24.33	9.52
North M	Upper	02/21/90	5-10	31	28	29	29.33		
North M	Upper	02/21/90	10-15	29	28	30	29.00		
North M	Upper	02/21/90	15+	20	5	3	9.33		
North M	Upper	03/28/90	0-5	18	16	14	16.00	15.25	7.52
North M	Upper	03/28/90	5-10	14	18	18	16.67		
North M	Upper	03/28/90	10-15	26	25	20	23.67		
North M	Upper	03/28/90	15+	12	2	0	4.67		
North M	Upper	04/25/90	0-5	21	22	18	20.33	16.50	9.57
North M	Upper	04/25/90	5-10	8	26	30	21.33		
North M	Upper	04/25/90	10-15	28	18	15	20.33		
North M	Upper	04/25/90	15+	12	0	0	4.00		
North M	Upper	05/21/90	0-5	6	9	10	8.33	9.25	5.25
North M	Upper	05/21/90	5-10	10	13	14	12.33		
North M	Upper	05/21/90	10-15	23	5	4	10.67		
North M	Upper	05/21/90	15+	8	5	4	5.67		
North M	Upper	06/22/90	0-5	17	14	18	16.33	13.83	5.03
North M	Upper	06/22/90	5-10	13	17	7	12.33		
North M	Upper	06/22/90	10-15	17	18	21	18.67		
North M	Upper	06/22/90	15+	10	3	11	8.00		
North M	Upper	07/24/90	0-5	14	12	17	14.33	11.58	4.27
North M	Upper	07/24/90	5-10	18	14	10	14.00		
North M	Upper	07/24/90	10-15	11	12	15	12.67		
North M	Upper	07/24/90	15+	5	4	7	5.33		
North M	Upper	08/17/90	0-5	13	15	8	12.00	8.58	5.85
North M	Upper	08/17/90	5-10	4	9	6	6.33		
North M	Upper	08/17/90	10-15	23	0	3	8.67		
North M	Upper	08/17/90	15+	6	7	9	7.33		
North M	Upper	09/21/90	0-5	0	0	0	0.00	1.08	2.10
North M	Upper	09/21/90	5-10	0	0	0	0.00		
North M	Upper	09/21/90	10-15	0	0	0	0.00		
North M	Upper	09/21/90	15+	7	3	3	4.33		
North M	Upper	10/19/90	0-5	3	7	8	6.00	7.75	5.49
North M	Upper	10/19/90	5-10	0	4	5	3.00		
North M	Upper	10/19/90	10-15	15	3	10	9.33		
North M	Upper	10/19/90	15+	9	8	21	12.67		
North M	Upper	11/20/90	0-5	13	5	0	6.00	8.33	9.26
North M	Upper	11/20/90	5-10	0	5	10	5.00		
North M	Upper	11/20/90	10-15	20	4	3	9.00		
North M	Upper	11/20/90	15+	33	5	2	13.33		

TABLE 6. Tidal Creek Uca data separated by transect and quadrat for each sampling date. Local = study site, Trans = transect, Quad = quadrat, Mean = mean of the three counts for each quadrat, Ave Mean = mean for all quadrats and all counts in the transect, Std Dev = standard deviation for all quadrats and all counts in the transect.

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Tidal C	Lower	12/26/89	0-5	112	114	115	113.67	60.50	32.48
Tidal C	Lower	12/26/89	5-10	64	52	52	56.00		
Tidal C	Lower	12/26/89	10-15	25	32	44	33.67		
Tidal C	Lower	12/26/89	15+	28	50	38	38.67		
Tidal C	Lower	01/26/90	0-5	70	75	56	67.00	54.33	14.99
Tidal C	Lower	01/26/90	5-10	65	64	72	67.00		
Tidal C	Lower	01/26/90	10-15	32	34	36	34.00		
Tidal C	Lower	01/26/90	15+	60	42	46	49.33		
Tidal C	Lower	02/21/90	0-5	38	61	63	54.00	33.92	14.37
Tidal C	Lower	02/21/90	5-10	20	16	28	21.33		
Tidal C	Lower	02/21/90	10-15	25	27	30	27.33		
Tidal C	Lower	02/21/90	15+	26	29	44	33.00		
Tidal C	Lower	03/30/90	0-5	70	50	37	52.33	34.08	12.93
Tidal C	Lower	03/30/90	5-10	36	28	32	32.00		
Tidal C	Lower	03/30/90	10-15	27	27	23	25.67		
Tidal C	Lower	03/30/90	15+	26	28	25	26.33		
Tidal C	Lower	04/26/90	0-5	58	62	56	58.67	44.33	16.71
Tidal C	Lower	04/26/90	5-10	68	70	42	60.00		
Tidal C	Lower	04/26/90	10-15	30	32	20	27.33		
Tidal C	Lower	04/26/90	15+	28	30	36	31.33		
Tidal C	Lower	05/21/90	0-5	39	38	35	37.33	22.83	9.45
Tidal C	Lower	05/21/90	5-10	30	20	18	22.67		
Tidal C	Lower	05/21/90	10-15	15	14	12	13.67		
Tidal C	Lower	05/21/90	15+	15	18	20	17.67		
Tidal C	Lower	06/22/90	0-5	52	67	56	58.33	35.25	14.70
Tidal C	Lower	06/22/90	5-10	32	41	32	35.00		
Tidal C	Lower	06/22/90	10-15	26	25	26	25.67		
Tidal C	Lower	06/22/90	15+	19	25	22	22.00		
Tidal C	Lower	07/24/90	0-5	81	84	62	75.67	44.08	19.70
Tidal C	Lower	07/24/90	5-10	44	39	31	38.00		
Tidal C	Lower	07/24/90	10-15	37	37	29	34.33		
Tidal C	Lower	07/24/90	15+	36	28	21	28.33		
Tidal C	Lower	08/17/90	0-5	37	78	69	61.33	53.25	12.14
Tidal C	Lower	08/17/90	5-10	54	58	63	58.33		
Tidal C	Lower	08/17/90	10-15	54	57	46	52.33		
Tidal C	Lower	08/17/90	15+	43	41	39	41.00		
Tidal C	Lower	09/24/90	0-5	0	0	0	0.00	4.83	4.20
Tidal C	Lower	09/24/90	5-10	6	13	12	10.33		
Tidal C	Lower	09/24/90	10-15	4	3	2	3.00		
Tidal C	Lower	09/24/90	15+	5	5	8	6.00		
Tidal C	Lower	10/19/90	0-5	0	10	12	7.33	8.08	4.27
Tidal C	Lower	10/19/90	5-10	5	5	6	5.33		
Tidal C	Lower	10/19/90	10-15	9	6	5	6.67		
Tidal C	Lower	10/19/90	15+	9	15	15	13.00		
Tidal C	Lower	11/20/90	0-5	11	6	11	9.33	8.58	2.87
Tidal C	Lower	11/20/90	5-10	13	10	7	10.00		
Tidal C	Lower	11/20/90	10-15	8	13	5	8.67		
Tidal C	Lower	11/20/90	15+	4	7	8	6.33		

TABLE 6. Continued

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Tidal C	Upper	12/26/89	0-5	52	61	65	59.33	44.25	11.80
Tidal C	Upper	12/26/89	5-10	30	35	41	35.33		
Tidal C	Upper	12/26/89	10-15	34	40	36	36.67		
Tidal C	Upper	12/26/89	15+	36	39	62	45.67		
Tidal C	Upper	01/26/90	0-5	32	30	30	30.67	31.17	4.62
Tidal C	Upper	01/26/90	5-10	38	25	28	30.33		
Tidal C	Upper	01/26/90	10-15	29	31	24	28.00		
Tidal C	Upper	01/26/90	15+	36	40	31	35.67		
Tidal C	Upper	02/21/90	0-5	29	23	24	25.33	23.92	5.20
Tidal C	Upper	02/21/90	5-10	24	18	13	18.33		
Tidal C	Upper	02/21/90	10-15	28	26	34	29.33		
Tidal C	Upper	02/21/90	15+	21	21	26	22.67		
Tidal C	Upper	03/30/90	0-5	25	26	20	23.67	29.42	6.08
Tidal C	Upper	03/30/90	5-10	26	40	26	30.67		
Tidal C	Upper	03/30/90	10-15	39	37	32	36.00		
Tidal C	Upper	03/30/90	15+	30	28	24	27.33		
Tidal C	Upper	04/26/90	0-5	22	29	29	26.67	25.58	3.95
Tidal C	Upper	04/26/90	5-10	20	25	20	21.67		
Tidal C	Upper	04/26/90	10-15	22	26	26	24.67		
Tidal C	Upper	04/26/90	15+	33	25	30	29.33		
Tidal C	Upper	05/21/90	0-5	10	12	16	12.67	11.75	2.17
Tidal C	Upper	05/21/90	5-10	9	8	12	9.67		
Tidal C	Upper	05/21/90	10-15	11	11	11	11.00		
Tidal C	Upper	05/21/90	15+	14	13	14	13.67		
Tidal C	Upper	06/22/90	0-5	27	25	24	25.33	22.17	3.62
Tidal C	Upper	06/22/90	5-10	15	20	23	19.33		
Tidal C	Upper	06/22/90	10-15	18	21	20	19.67		
Tidal C	Upper	06/22/90	15+	20	26	27	24.33		
Tidal C	Upper	07/24/90	0-5	25	22	29	25.33	28.42	9.09
Tidal C	Upper	07/24/90	5-10	17	21	23	20.33		
Tidal C	Upper	07/24/90	10-15	19	51	34	34.67		
Tidal C	Upper	07/24/90	15+	31	37	32	33.33		
Tidal C	Upper	08/17/90	0-5	29	37	46	37.33	42.58	6.40
Tidal C	Upper	08/17/90	5-10	43	39	44	42.00		
Tidal C	Upper	08/17/90	10-15	39	38	47	41.33		
Tidal C	Upper	08/17/90	15+	46	55	48	49.67		
Tidal C	Upper	09/24/90	0-5	0	2	0	0.67	3.00	2.65
Tidal C	Upper	09/24/90	5-10	2	6	0	2.67		
Tidal C	Upper	09/24/90	10-15	3	2	2	2.33		
Tidal C	Upper	09/24/90	15+	5	5	9	6.33		
Tidal C	Upper	10/19/90	0-5	9	14	12	11.67	21.42	14.57
Tidal C	Upper	10/19/90	5-10	12	18	16	15.33		
Tidal C	Upper	10/19/90	10-15	13	13	14	13.33		
Tidal C	Upper	10/19/90	15+	41	38	57	45.33		
Tidal C	Upper	11/20/90	0-5	8	12	12	10.67	16.50	7.40
Tidal C	Upper	11/20/90	5-10	11	15	15	13.67		
Tidal C	Upper	11/20/90	10-15	12	20	12	14.67		
Tidal C	Upper	11/20/90	15+	18	30	33	27.00		

TABLE 7. Blue Hole Point <u>Uca</u> data separated by transect and quadrat for each sampling date. Local = study site, Trans = transect, Quad = quadrat, Mean = mean of the three counts for each quadrat, Ave Mean = mean for all quadrats and all counts in the transect, Std Dev = standard deviation for all quadrats and all counts in the transect.

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Bl Hl Pt	Lower	12/26/89	0-5	0	30	50	26.67	34.75	19.67
Bl Hl Pt	Lower	12/26/89	5-10	25	30	31	28.67		
Bl Hl Pt	Lower	12/26/89	10-15	13	16	51	26.67		
Bl Hl Pt	Lower	12/26/89	15+	40	70	61	57.00		
Bl Hl Pt	Lower	01/26/90	0-5	12	25	26	21.00	35.58	16.36
Bl Hl Pt	Lower	01/26/90	5-10	32	46	32	36.67		
Bl Hl Pt	Lower	01/26/90	10-15	24	28	29	27.00		
Bl Hl Pt	Lower	01/26/90	15+	72	63	38	57.67		
Bl Hl Pt	Lower	02/21/90	0-5	8	12	19	13.00	25.00	11.61
Bl Hl Pt	Lower	02/21/90	5-10	28	5	18	17.00		
Bl Hl Pt	Lower	02/21/90	10-15	30	39	33	34.00		
Bl Hl Pt	Lower	02/21/90	15+	36	39	33	36.00		
Bl Hl Pt	Lower	03/30/90	0-5	0	17	12	9.67	31.33	27.05
Bl Hl Pt	Lower	03/30/90	5-10	18	20	28	22.00		
Bl Hl Pt	Lower	03/30/90	10-15	8	12	35	18.33		
Bl Hl Pt	Lower	03/30/90	15+	74	85	67	75.33		
Bl Hl Pt	Lower	04/26/90	0-5	25	24	18	22.33	20.50	9.55
Bl Hl Pt	Lower	04/26/90	5-10	36	40	20	32.00		
Bl Hl Pt	Lower	04/26/90	10-15	20	12	18	16.67		
Bl Hl Pt	Lower	04/26/90	15+	10	5	18	11.00		
Bl Hl Pt	Lower	05/21/90	0-5	27	19	25	23.67	22.25	11.82
Bl Hl Pt	Lower	05/21/90	5-10	37	36	29	34.00		
Bl Hl Pt	Lower	05/21/90	10-15	36	20	25	27.00		
Bl Hl Pt	Lower	05/21/90	15+	1	7	5	4.33		
Bl Hl Pt	Lower	06/22/90	0-5	47	30	29	35.33	24.75	12.22
Bl Hl Pt	Lower	06/22/90	5-10	14	38	38	30.00		
Bl Hl Pt	Lower	06/22/90	10-15	16	32	14	20.67		
Bl Hl Pt	Lower	06/22/90	15+	7	10	22	13.00		
Bl Hl Pt	Lower	07/24/90	0-5	28	27	31	28.67	11.58	10.89
Bl Hl Pt	Lower	07/24/90	5-10	6	10	3	6.33		
Bl Hl Pt	Lower	07/24/90	10-15	3	8	18	9.67		
Bl Hl Pt	Lower	07/24/90	15+	0	1	4	1.67		
Bl Hl Pt	Lower	08/17/90	0-5	37	78	69	61.33	53.25	12.14
Bl Hl Pt	Lower	08/17/90	5-10	54	58	63	58.33		
Bl Hl Pt	Lower	08/17/90	10-15	54	57	46	52.33		
Bl Hl Pt	Lower	08/17/90	15+	43	41	39	41.00		
Bl Hl Pt	Lower	09/21/90	0-5	28	9	23	20.00	9.58	8.65
Bl Hl Pt	Lower	09/21/90	5-10	17	12	0	9.67		
Bl Hl Pt	Lower	09/21/90	10-15	7	8	7	7.33		
Bl Hl Pt	Lower	09/21/90	15+	1	0	3	1.33		
Bl Hl Pt	Lower	10/19/90	0-5	0	0	0	0.00	3.00	3.29
Bl Hl Pt	Lower	10/19/90	5-10	1	0	1	0.67		
Bl Hl Pt	Lower	10/19/90	10-15	2	5	5	4.00		
Bl Hl Pt	Lower	10/19/90	15+	11	6	5	7.33		
Bl Hl Pt	Lower	11/20/90	0-5	0	0	0	0.00	0.00	0.00
Bl Hl Pt	Lower	11/20/90	5-10	0	0	0	0.00		
Bl Hl Pt	Lower	11/20/90	10-15	0	0	0	0.00		
Bl Hl Pt	Lower	11/20/90	15+	0	0	0	0.00		

TABLE 7. Continued

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Bl Hl Pt	Upper	12/26/89	0-5	0	40	60	33.33	31.50	28.60
Bl Hl Pt	Upper	12/26/89	5-10	25	22	20	22.33		
Bl Hl Pt	Upper	12/26/89	10-15	60	73	78	70.33		
Bl Hl Pt	Upper	12/26/89	15+	0	0	0	0.00		
Bl Hl Pt	Upper	01/26/90	0-5	9	12	7	9.33	19.17	16.24
Bl Hl Pt	Upper	01/26/90	5-10	29	48	25	34.00		
Bl Hl Pt	Upper	01/26/90	10-15	22	38	40	33.33		
Bl Hl Pt	Upper	01/26/90	15+	0	0	0	0.00		
Bl Hl Pt	Upper	02/21/90	0-5	3	3	25	10.33	14.67	12.08
Bl Hl Pt	Upper	02/21/90	5-10	22	22	29	24.33		
Bl Hl Pt	Upper	02/21/90	10-15	34	18	20	24.00		
Bl Hl Pt	Upper	02/21/90	15+	0	0	0	0.00		
Bl Hl Pt	Upper	03/30/90	0-5	0	0	27	9.00	15.50	21.92
Bl Hl Pt	Upper	03/30/90	5-10	0	7	4	3.67		
Bl Hl Pt	Upper	03/30/90	10-15	67	34	47	49.33		
Bl Hl Pt	Upper	03/30/90	15+	0	0	0	0.00		
Bl Hl Pt	Upper	04/26/90	0-5	18	15	28	20.33	19.00	4.81
Bl Hl Pt	Upper	04/26/90	5-10	14	18	17	16.33		
Bl Hl Pt	Upper	04/26/90	10-15	27	26	18	23.67		
Bl Hl Pt	Upper	04/26/90	15+	17	15	15	15.67		
Bl Hl Pt	Upper	05/21/90	0-5	20	23	18	20.33	18.83	4.16
Bl Hl Pt	Upper	05/21/90	5-10	16	17	14	15.67		
Bl Hl Pt	Upper	05/21/90	10-15	22	28	13	21.00		
Bl Hl Pt	Upper	05/21/90	15+	18	15	22	18.33		
Bl Hl Pt	Upper	06/22/90	0-5	22	28	36	28.67	19.67	6.74
Bl Hl Pt	Upper	06/22/90	5-10	18	13	19	16.67		
Bl Hl Pt	Upper	06/22/90	10-15	22	17	17	18.67		
Bl Hl Pt	Upper	06/22/90	15+	15	9	20	14.67		
Bl Hl Pt	Upper	07/24/90	0-5	25	22	19	22.00	18.92	5.79
Bl Hl Pt	Upper	07/24/90	5-10	23	26	18	22.33		
Bl Hl Pt	Upper	07/24/90	10-15	16	26	21	21.00		
Bl Hl Pt	Upper	07/24/90	15+	10	12	9	10.33		
Bl Hl Pt	Upper	08/17/90	0-5	18	27	26	23.67	39.17	10.19
Bl Hl Pt	Upper	08/17/90	5-10	43	39	44	42.00		
Bl Hl Pt	Upper	08/17/90	10-15	39	38	47	41.33		
Bl Hl Pt	Upper	08/17/90	15+	46	55	48	49.67		
Bl Hl Pt	Upper	09/21/90	0-5	1	0	2	1.00	14.33	13.62
Bl Hl Pt	Upper	09/21/90	5-10	2	5	4	3.67		
Bl Hl Pt	Upper	09/21/90	10-15	8	26	33	22.33		
Bl Hl Pt	Upper	09/21/90	15+	29	26	36	30.33		
Bl Hl Pt	Upper	10/19/90	0-5	38	27	24	29.67	20.50	11.38
Bl Hl Pt	Upper	10/19/90	5-10	29	42	23	31.33		
Bl Hl Pt	Upper	10/19/90	10-15	8	13	16	12.33		
Bl Hl Pt	Upper	10/19/90	15+	8	9	9	8.67		
Bl Hl Pt	Upper	11/20/90	0-5	22	44	36	34.00	26.33	9.14
Bl Hl Pt	Upper	11/20/90	5-10	40	31	27	32.67		
Bl Hl Pt	Upper	11/20/90	10-15	21	25	19	21.67		
Bl Hl Pt	Upper	11/20/90	15+	21	15	15	17.00		

TABLE 8. Grand Harbor <u>Uca</u> data separated by transect and quadrat for each sampling date. Local = study site, Trans = transect, Quad = quadrat, Mean = mean of the three counts for each quadrat, Ave Mean = mean for all quadrats and all counts in the transect, Std Dev = standard deviation for all quadrats and all counts in the transect.

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Grand H	Lower	12/26/89	0-5	3	6	7	5.33	6.75	3.65
Grand H	Lower	12/26/89	5-10	6	12	9	9.00		
Grand H	Lower	12/26/89	10-15	7	13	9	9.67		
Grand H	Lower	12/26/89	15+	2	0	7	3.00		
Grand H	Lower	01/27/90	0-5	1	6	4	3.67	5.50	2.93
Grand H	Lower	01/27/90	5-10	10	10	5	8.33		
Grand H	Lower	01/27/90	10-15	9	6	5	6.67		
Grand H	Lower	01/27/90	15+	6	3	1	3.33		
Grand H	Lower	02/23/90	0-5	0	0	0	0.00	1.25	1.23
Grand H	Lower	02/23/90	5-10	3	3	2	2.67		
Grand H	Lower	02/23/90	10-15	2	0	1	1.00		
Grand H	Lower	02/23/90	15+	3	0	1	1.33		
Grand H	Lower	03/26/90	0-5	7	4	4	5.00	5.58	1.85
Grand H	Lower	03/26/90	5-10	8	6	8	7.33		
Grand H	Lower	03/26/90	10-15	6	4	5	5.00		
Grand H	Lower	03/26/90	15+	8	5	2	5.00		
Grand H	Lower	04/25/90	0-5	6	2	7	5.00	2.67	2.53
Grand H	Lower	04/25/90	5-10	3	7	1	3.67		
Grand H	Lower	04/25/90	10-15	0	3	2	1.67		
Grand H	Lower	04/25/90	15+	1	0	0	0.33		
Grand H	Lower	05/22/90	0-5	17	11	14	14.00	7.08	5.92
Grand H	Lower	05/22/90	5-10	6	16	1	7.67		
Grand H	Lower	05/22/90	10-15	7	7	5	6.33		
Grand H	Lower	05/22/90	15+	1	0	0	0.33		
Grand H	Lower	06/23/90	0-5	3	2	0	1.67	5.58	5.30
Grand H	Lower	06/23/90	5-10	13	10	17	13.33		
Grand H	Lower	06/23/90	10-15	8	6	6	6.67		
Grand H	Lower	06/23/90	15+	2	0	0	0.67		
Grand H	Lower	07/24/90	0-5	34	12	27	24.33	13.25	9.93
Grand H	Lower	07/24/90	5-10	14	16	15	15.00		
Grand H	Lower	07/24/90	10-15	6	12	20	12.67		
Grand H	Lower	07/24/90	15+	2	0	1	1.00		
Grand H	Lower	08/17/90	0-5	8	14	12	11.33	27.42	20.77
Grand H	Lower	08/17/90	5-10	36	32	49	39.00		
Grand H	Lower	08/17/90	10-15	31	69	56	52.00		
Grand H	Lower	08/17/90	15+	12	8	2	7.33		
Grand H	Lower	09/20/90	0-5	0	0	0	0.00	0.00	0.00
Grand H	Lower	09/20/90	5-10	0	0	0	0.00		
Grand H	Lower	09/20/90	10-15	0	0	0	0.00		
Grand H	Lower	09/20/90	15+	0	0	0	0.00		
Grand H	Lower	10/18/90	0-5	0	0	0	0.00	0.08	0.28
Grand H	Lower	10/18/90	5-10	0	0	0	0.00		
Grand H	Lower	10/18/90	10-15	0	0	0	0.00		
Grand H	Lower	10/18/90	15+	1	0	0	0.33		
Grand H	Lower	11/19/90	0-5	0	0	0	0.00	0.00	0.00
Grand H	Lower	11/19/90	5-10	0	0	0	0.00		
Grand H	Lower	11/19/90	10-15	0	0	0	0.00		
Grand H	Lower	11/19/90	15+	0	0	0	0.00		

TABLE 8. Continued

Local	Trans	Date	Quad	Count 1	Count 2	Count 3	Mean	Ave Mean	Std Dev
Grand H	Upper	12/26/89	0-5	25	18	13	18.67	33.50	10.31
Grand H	Upper	12/26/89	5-10	39	43	27	36.33		
Grand H	Upper	12/26/89	10-15	43	36	30	36.33		
Grand H	Upper	12/26/89	15+	40	46	42	42.67		
Grand H	Upper	01/27/90	0-5	25	28	22	25.00	33.08	7.38
Grand H	Upper	01/27/90	5-10	34	40	44	39.33		
Grand H	Upper	01/27/90	10-15	43	38	34	38.33		
Grand H	Upper	01/27/90	15+	30	37	22	29.67		
Grand H	Upper	02/23/90	0-5	30	46	38	38.00	33.33	9.59
Grand H	Upper	02/23/90	5-10	20	35	25	26.67		
Grand H	Upper	02/23/90	10-15	18	35	25	26.00		
Grand H	Upper	02/23/90	15+	45	35	48	42.67		
Grand H	Upper	03/26/90	0-5	16	24	23	21.00	21.25	4.21
Grand H	Upper	03/26/90	5-10	20	27	19	22.00		
Grand H	Upper	03/26/90	10-15	20	24	30	24.67		
Grand H	Upper	03/26/90	15+	18	16	18	17.33		
Grand H	Upper	04/25/90	0-5	15	27	13	18.33	28.17	7.37
Grand H	Upper	04/25/90	5-10	33	27	32	30.67		
Grand H	Upper	04/25/90	10-15	39	32	36	35.67		
Grand H	Upper	04/25/90	15+	25	29	30	28.00		
Grand H	Upper	05/22/90	0-5	26	22	18	22.00	19.00	4.65
Grand H	Upper	05/22/90	5-10	26	20	21	22.33		
Grand H	Upper	05/22/90	10-15	12	14	12	12.67		
Grand H	Upper	05/22/90	15+	17	23	17	19.00		
Grand H	Upper	06/23/90	0-5	28	34	31	31.00	27.33	5.28
Grand H	Upper	06/23/90	5-10	18	26	20	21.33		
Grand H	Upper	06/23/90	10-15	34	23	28	28.33		
Grand H	Upper	06/23/90	15+	24	27	35	28.67		
Grand H	Upper	07/24/90	0-5	18	18	21	19.00	22.67	4.35
Grand H	Upper	07/24/90	5-10	24	27	20	23.67		
Grand H	Upper	07/24/90	10-15	22	24	17	21.00		
Grand H	Upper	07/24/90	15+	32	21	28	27.00		
Grand H	Upper	08/17/90	0-5	35	53	43	43.67	42.00	7.51
Grand H	Upper	08/17/90	5-10	41	42	47	43.33		
Grand H	Upper	08/17/90	10-15	40	27	53	40.00		
Grand H	Upper	08/17/90	15+	32	44	47	41.00		
Grand H	Upper	09/20/90	0-5	0	0	0	0.00	0.00	0.00
Grand H	Upper	09/20/90	5-10	0	0	0	0.00		
Grand H	Upper	09/20/90	10-15	0	0	0	0.00		
Grand H	Upper	09/20/90	15+	0	0	0	0.00		
Grand H	Upper	10/18/90	0-5	16	92	0	36.00	12.50	24.31
Grand H	Upper	10/18/90	5-10	1	6	4	3.67		
Grand H	Upper	10/18/90	10-15	7	4	1	4.00		
Grand H	Upper	10/18/90	15+	6	5	8	6.33		
Grand H	Upper	11/19/90	0-5	9	0	0	3.00	0.75	2.49
Grand H	Upper	11/19/90	5-10	0	0	0	0.00		
Grand H	Upper	11/19/90	10-15	0	0	0	0.00		
Grand H	Upper	11/19/90	15+	0	0	0	0.00		

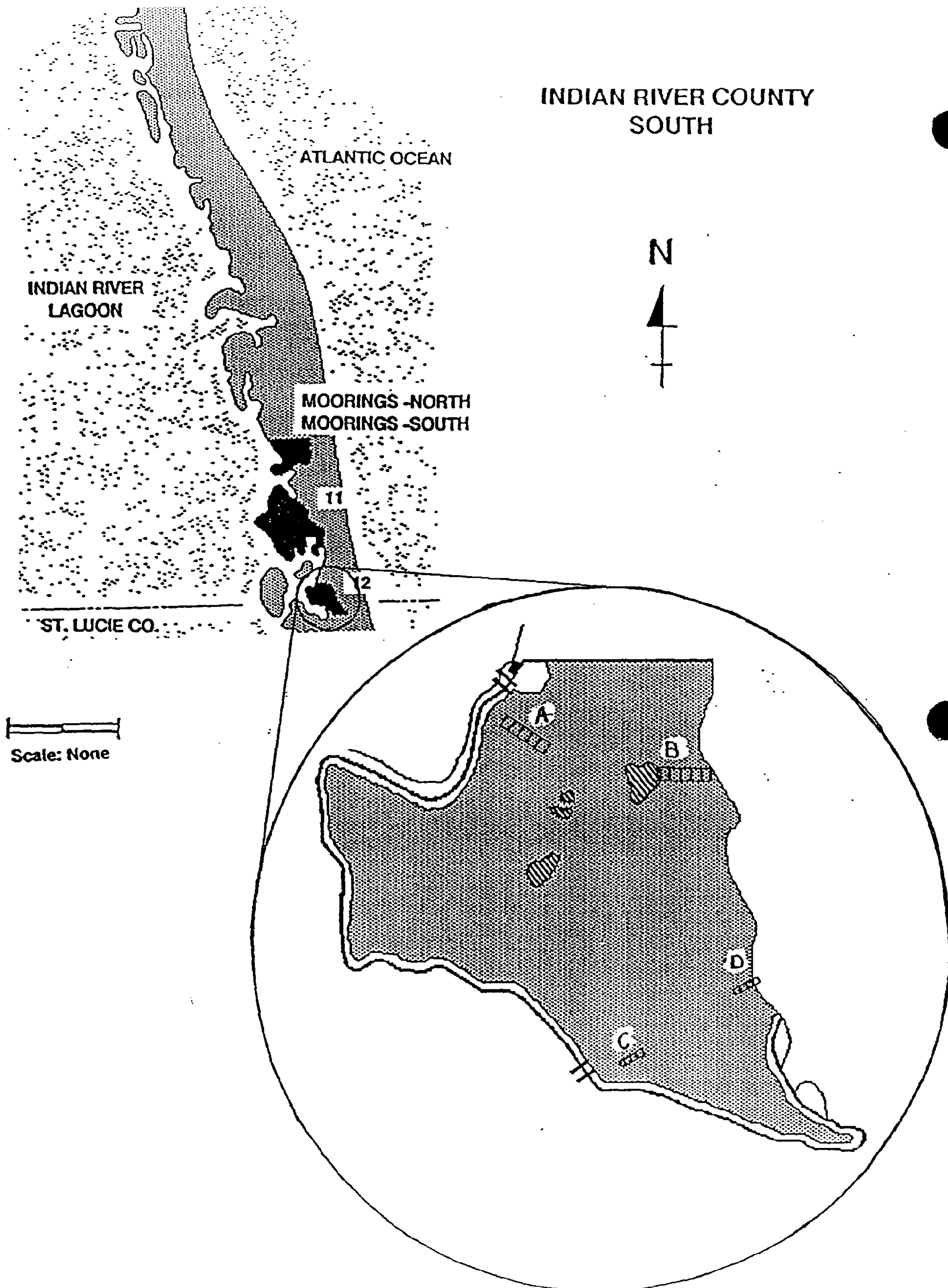


FIGURE 1. Impoundment 12 site map. A = lower <u>Cyprinodon</u> observation transect, B = upper <u>Cyprinodon</u> observation transect, C = lower <u>Uca</u> transect, D = upper <u>Uca</u> transect. From Rey and Kain, <u>A Guide to the Salt Marsh Impoundments of Florida</u>.

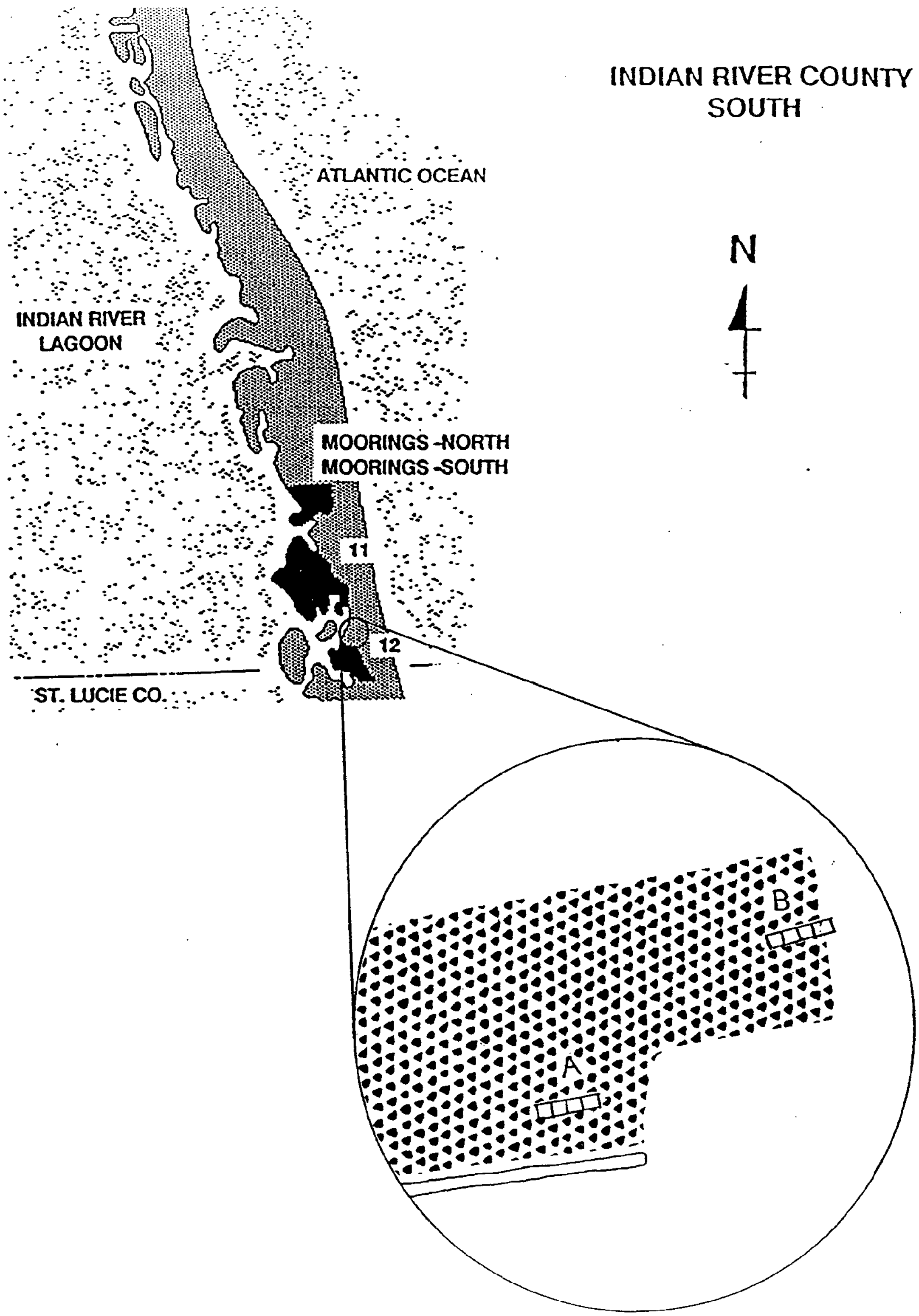


FIGURE 2. North Marsh site map. A = lower Uca transect, B = upper Uca transect. From Rey and Kain, A Guide to the Salt Marsh Impoundments of Florida.

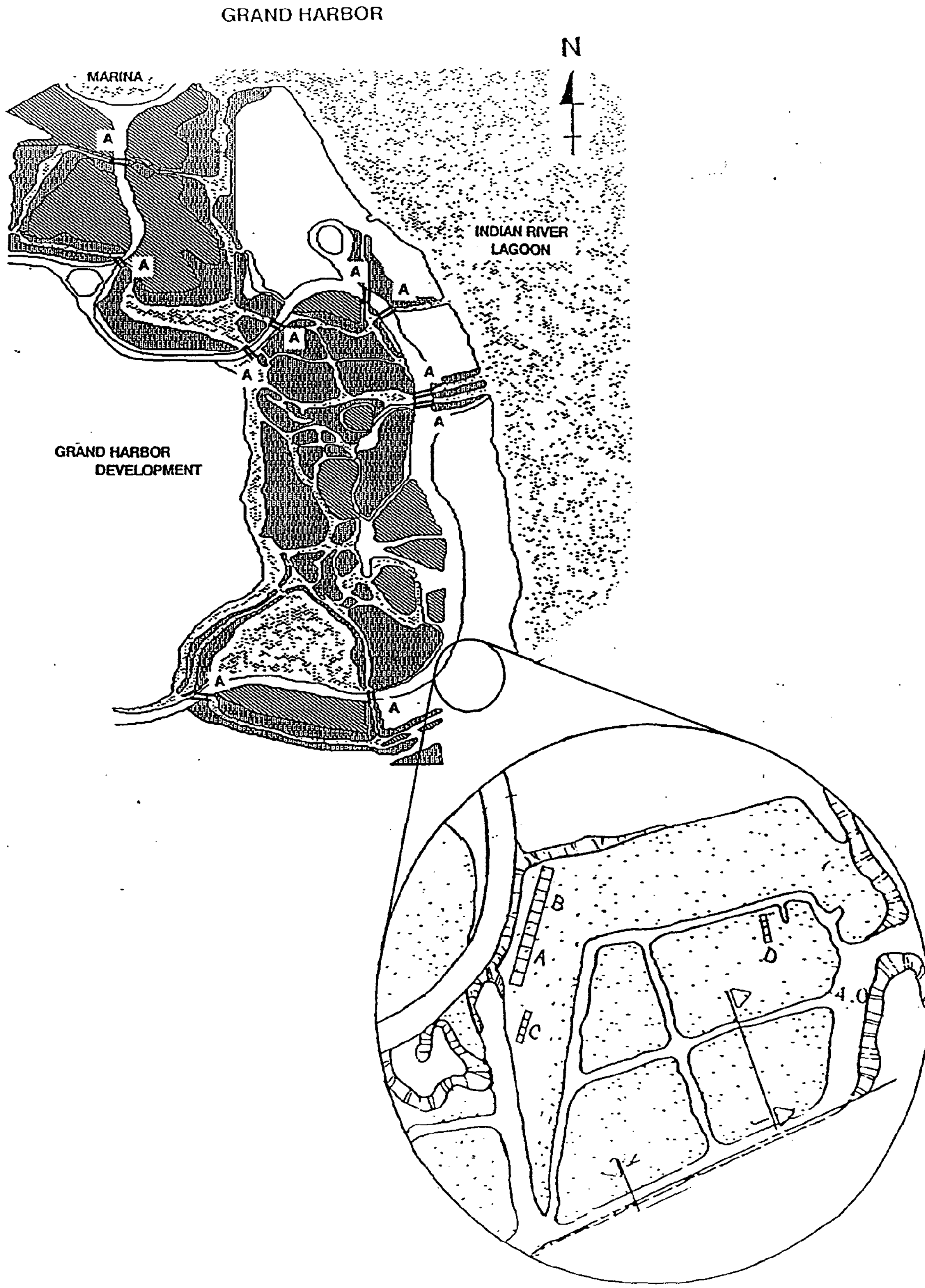


FIGURE 3. Grand Harbor site map. A = lower Cyprinodon observation transect, B = upper Cyprinodon observation transect, C = created Uca transect, D = natural Uca transect. From Rey and Kain, A Guide to the Salt Marsh Impoundments of Florida.

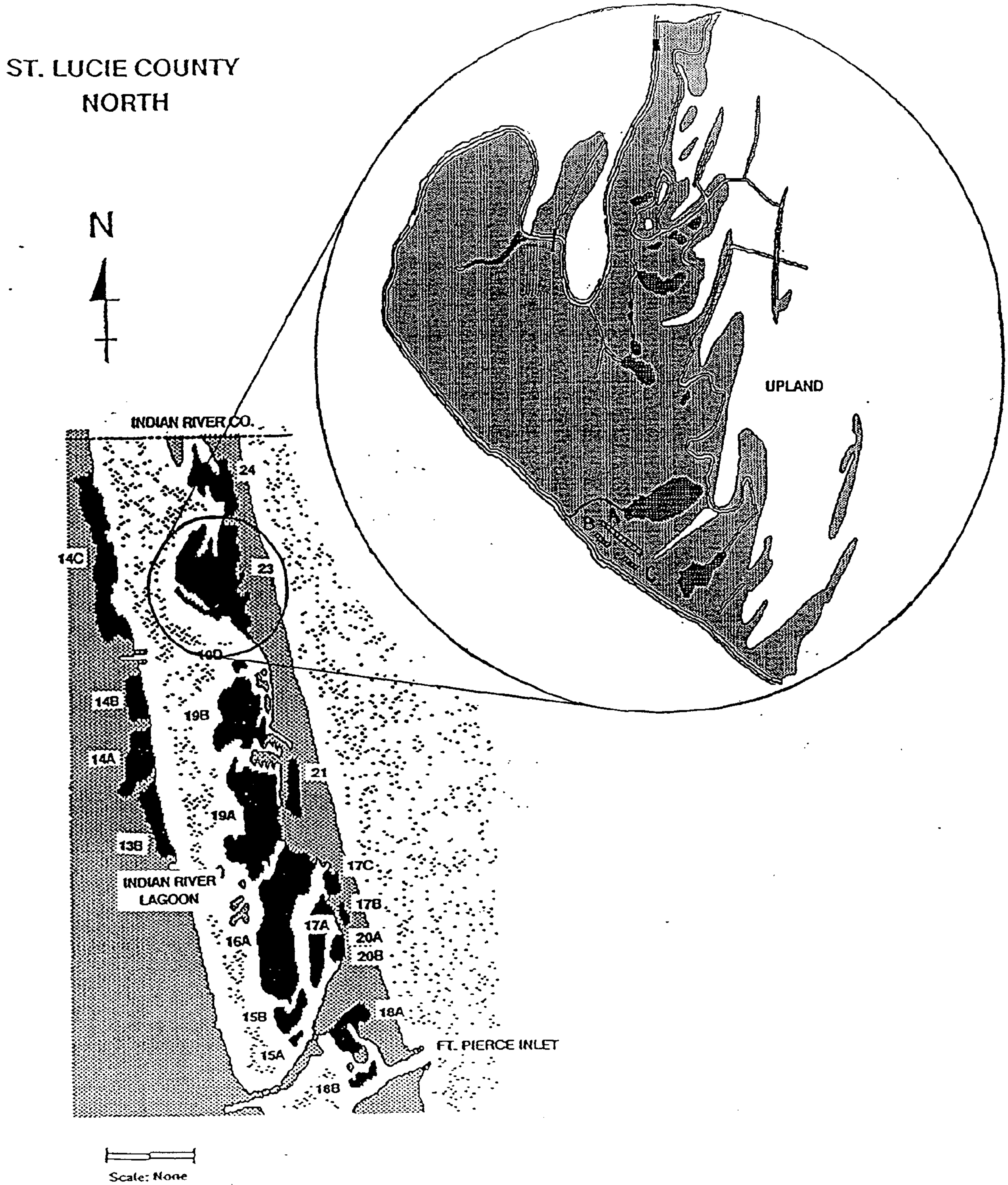


FIGURE 4. Blue Hole Point site map. A = <u>Cyprinodon</u> observation transect, B = lower <u>Uca</u> transect, C = upper <u>Uca</u> transect. From Rey and Kain, <u>A Guide to the Salt Marsh Impoundments of Florida</u>.

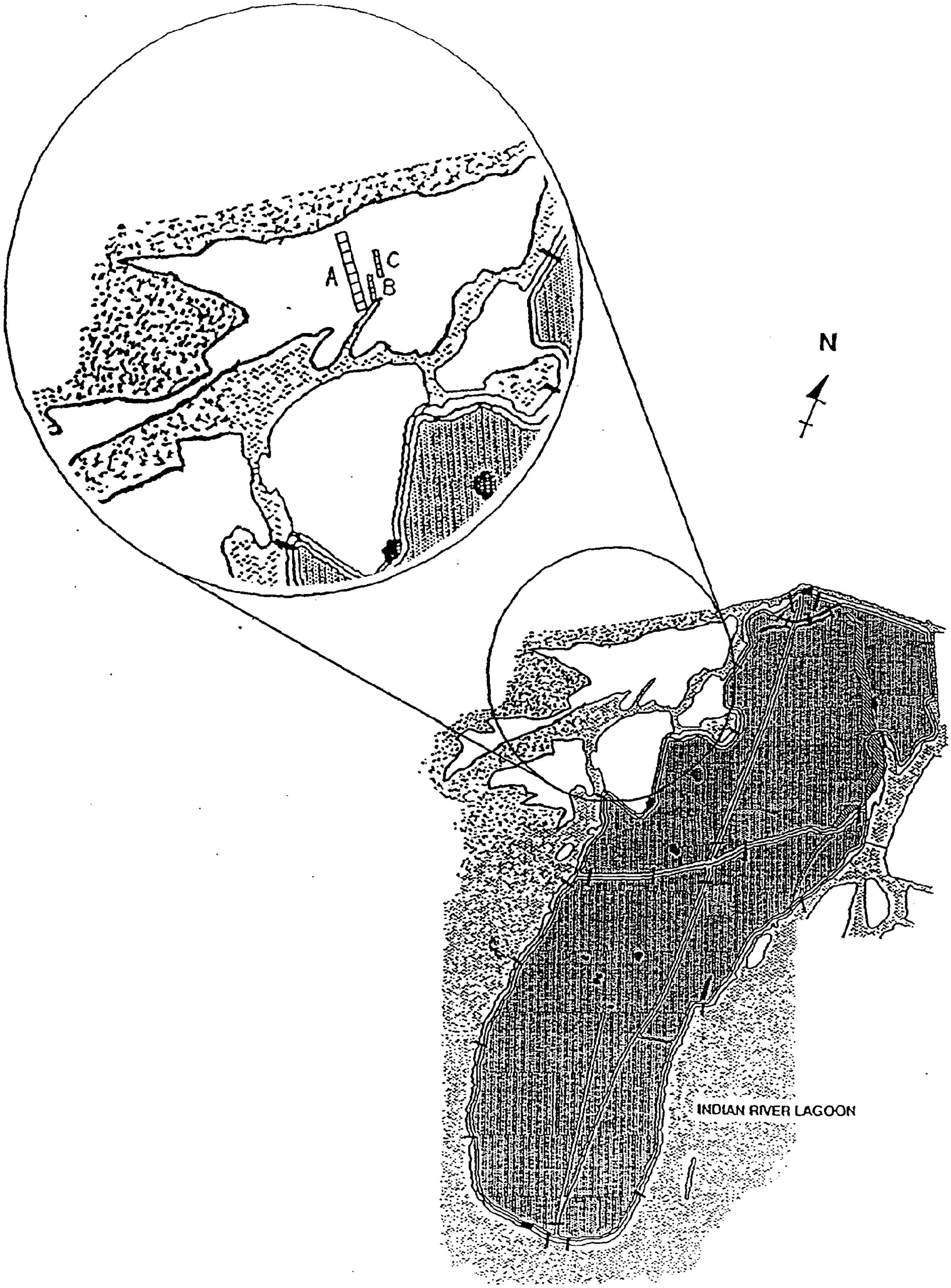


FIGURE 5. Tidal Creek site map. A = Cyprinodon observation transect, B = lower Uca transect, C = upper Uca transect. From Rey and Kain, A Guide to the Salt Marsh Impoundments of Florida.

FIELD OBSERVATIONS CZM/DER

LOCATION ______________ DATE ______________

QUAD TIME

SPECIES	CR	DEFEND	MATE	FEED	FLASH	OTHER	POS	NUM
CYP VAR								
POE LAT GAM HOL FUN ___								

QUAD TIME

SPECIES	CR	DEFEND	MATE	FEED	FLASH	OTHER	POS	NUM
CYP VAR								
POE LAT GAM HOL FUN ___								

QUAD TIME

SPECIES	CR	DEFEND	MATE	FEED	FLASH	OTHER	POS	NUM
CYP VAR								
POE LAT GAM HOL FUN ___								

QUAD TIME

SPECIES	CR	DEFEND	MATE	FEED	FLASH	OTHER	POS	NUM
CYP VAR								
POE LAT GAM HOL FUN ___								

QUAD TIME

SPECIES	CR	DEFEND	MATE	FEED	FLASH	OTHER	POS	NUM
CYP VAR								
POE LAT GAM HOL FUN ___								

FIGURE 6. Sample field data sheet for fish behavioral observations.

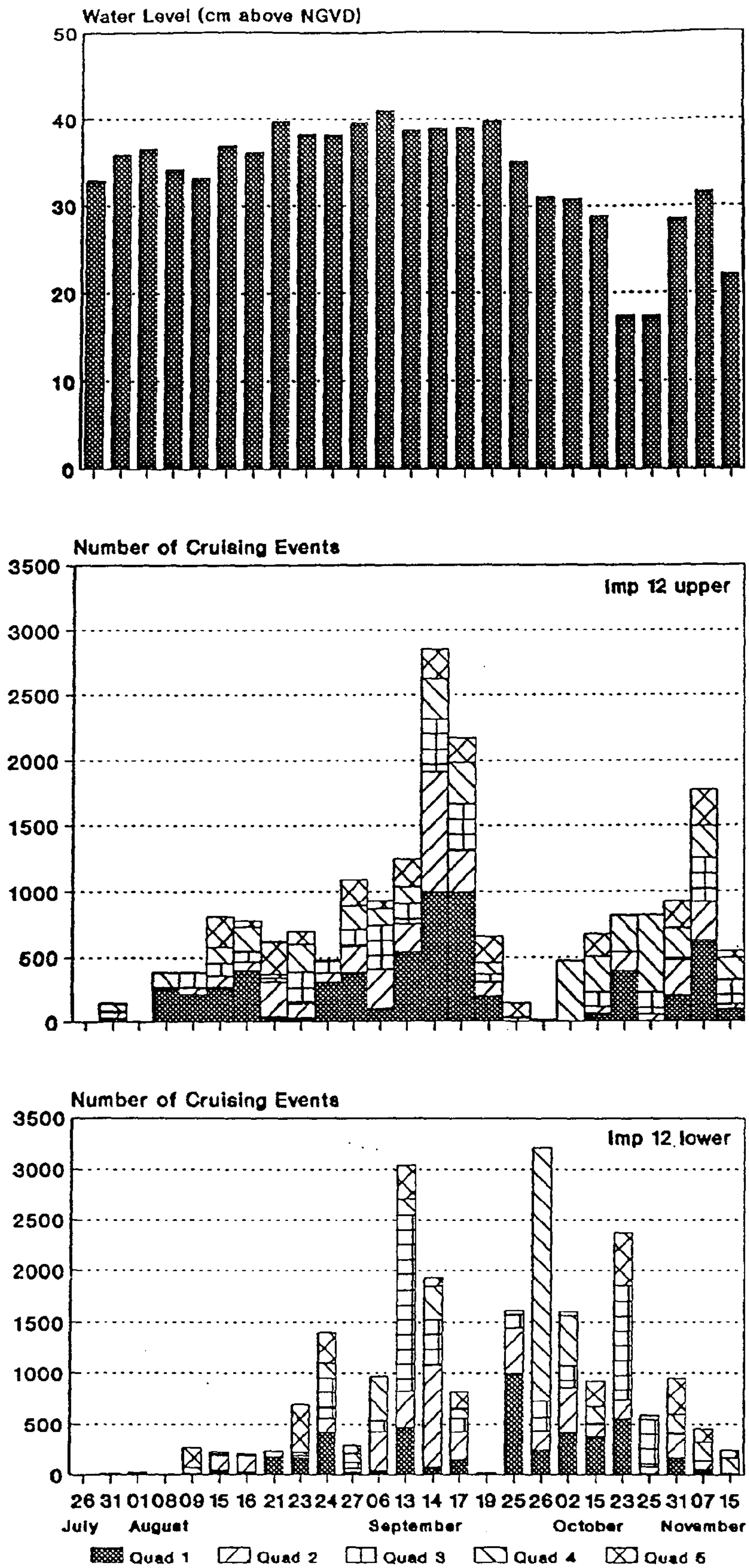


FIGURE 7. Total number of individual Cyprinodon cruising events in the lower and upper transects of Impoundment 12.

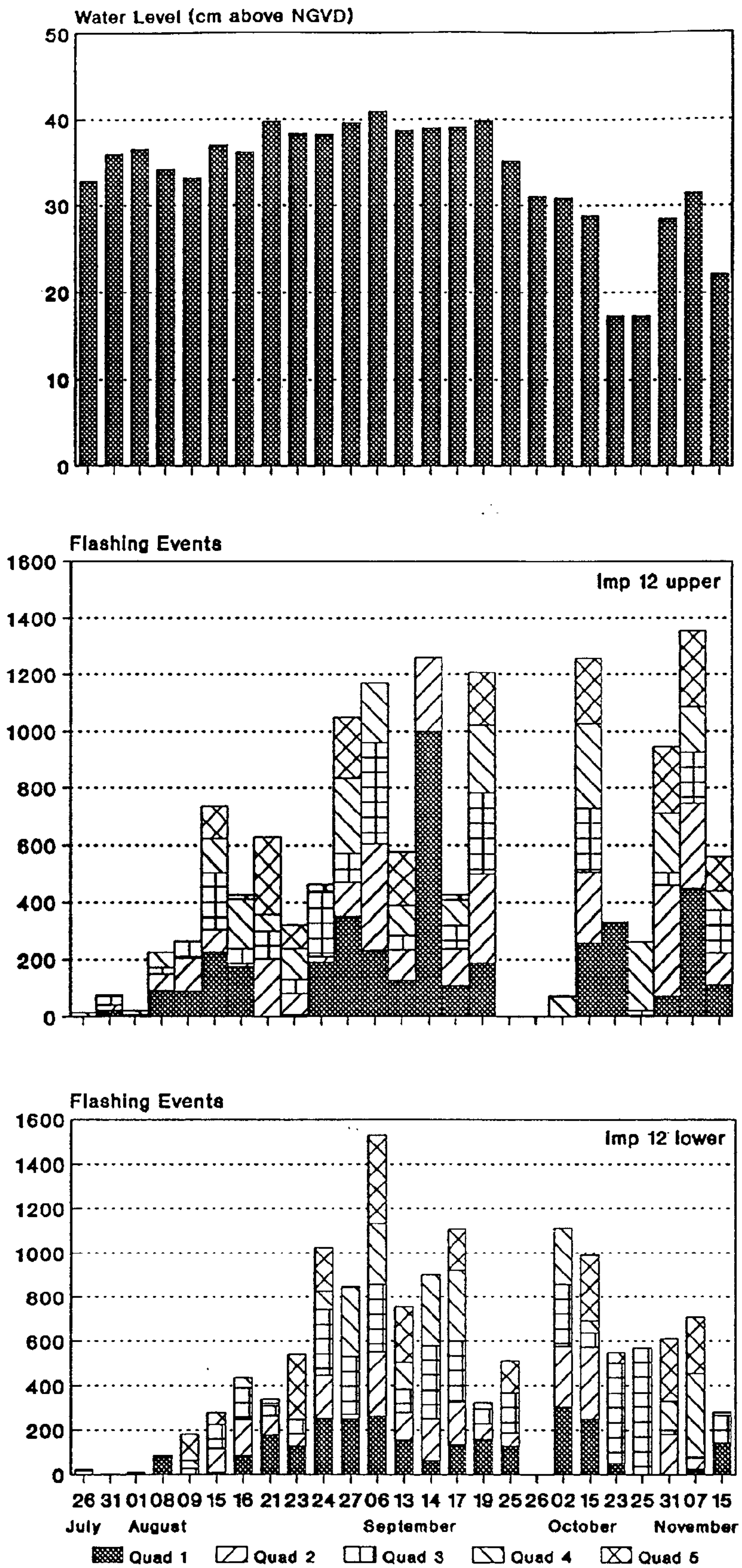


FIGURE 8. Total number of *Cyprinodon* flashing events in the lower and upper transects of Impoundment 12.

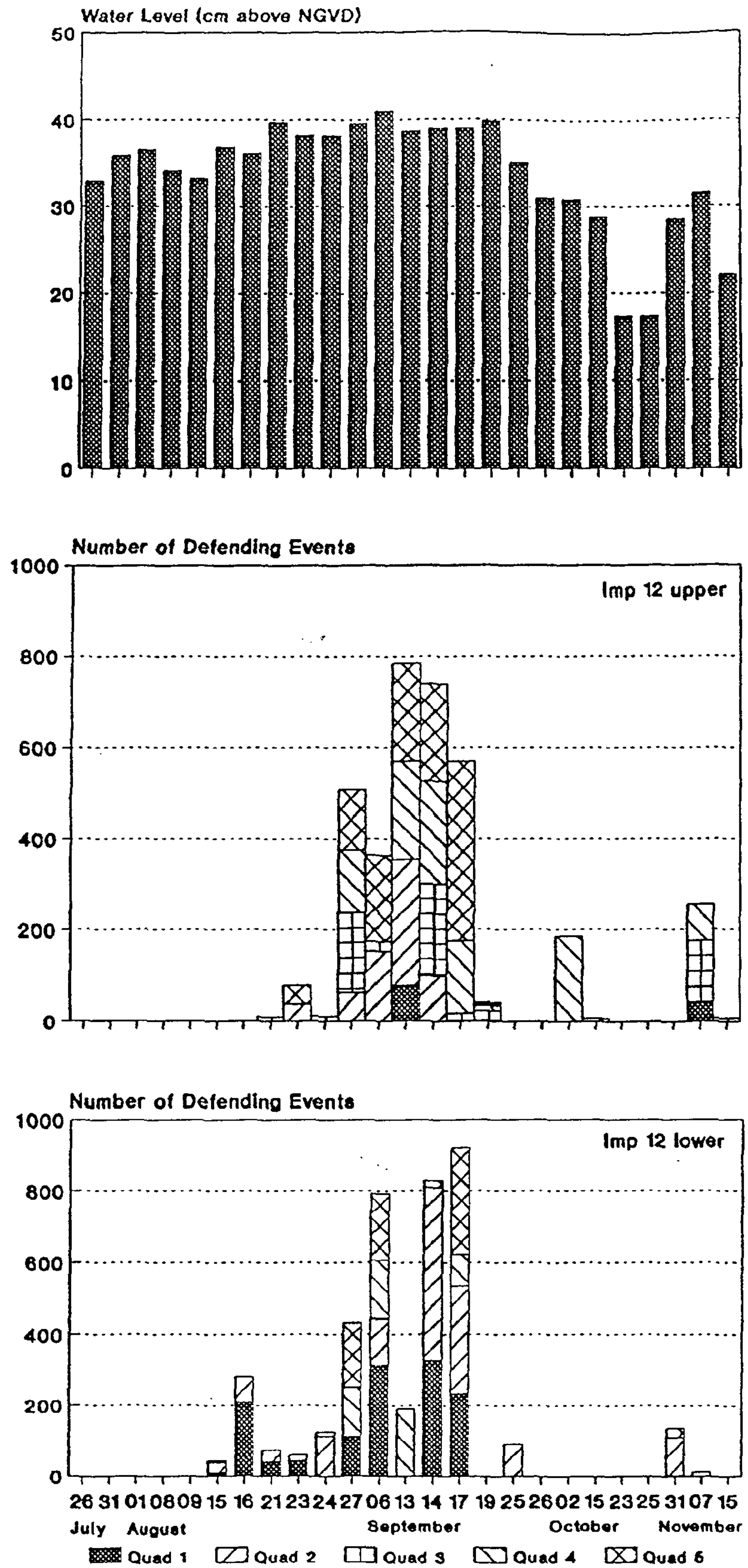


FIGURE 9. Total number of Cyprinodon defending events in the lower and upper transects of Impoundment 12.

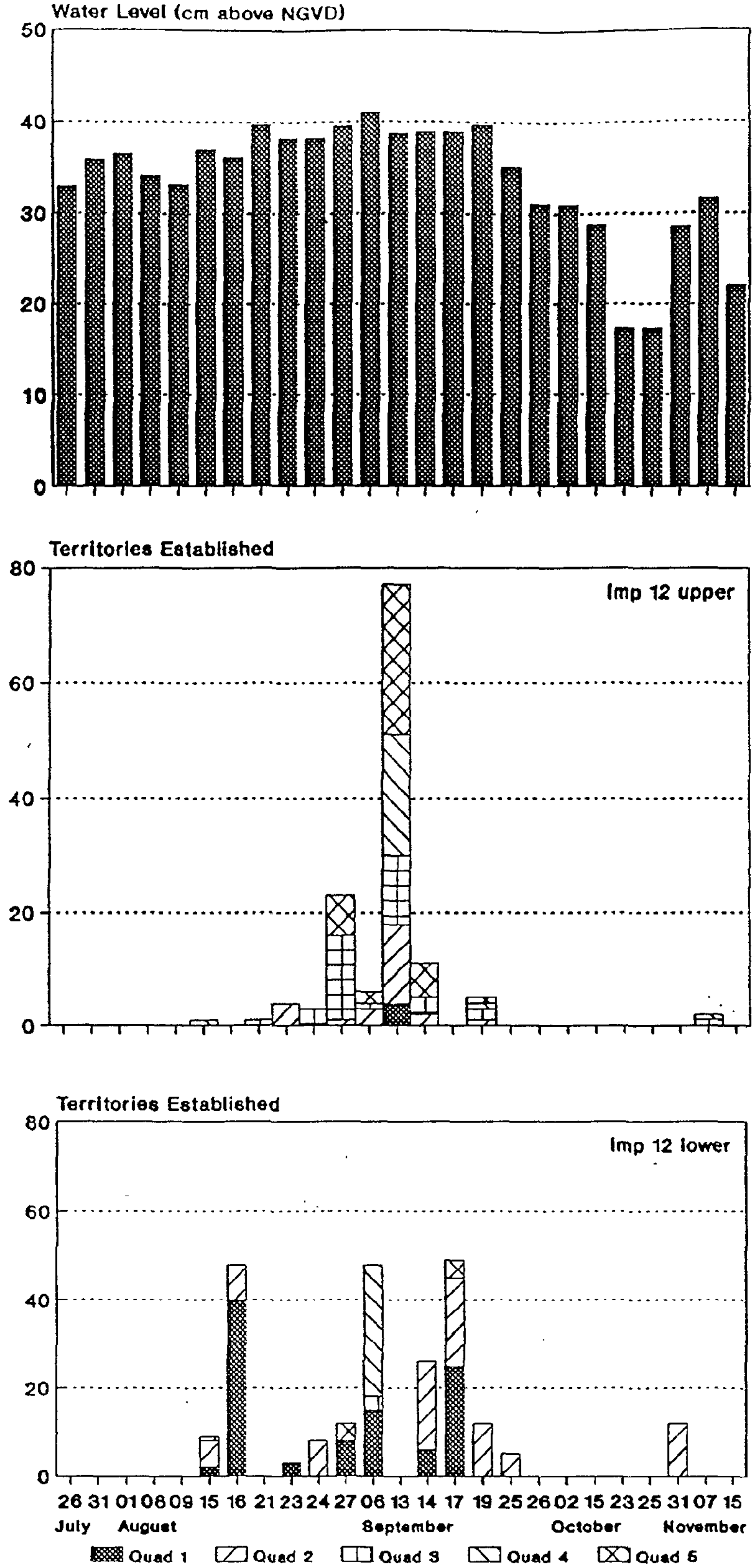


FIGURE 10. Observed Cyprinodon territories in the lower and upper transects of Impoundment 12 with to the mean daily water level measured in cm above NGVD.

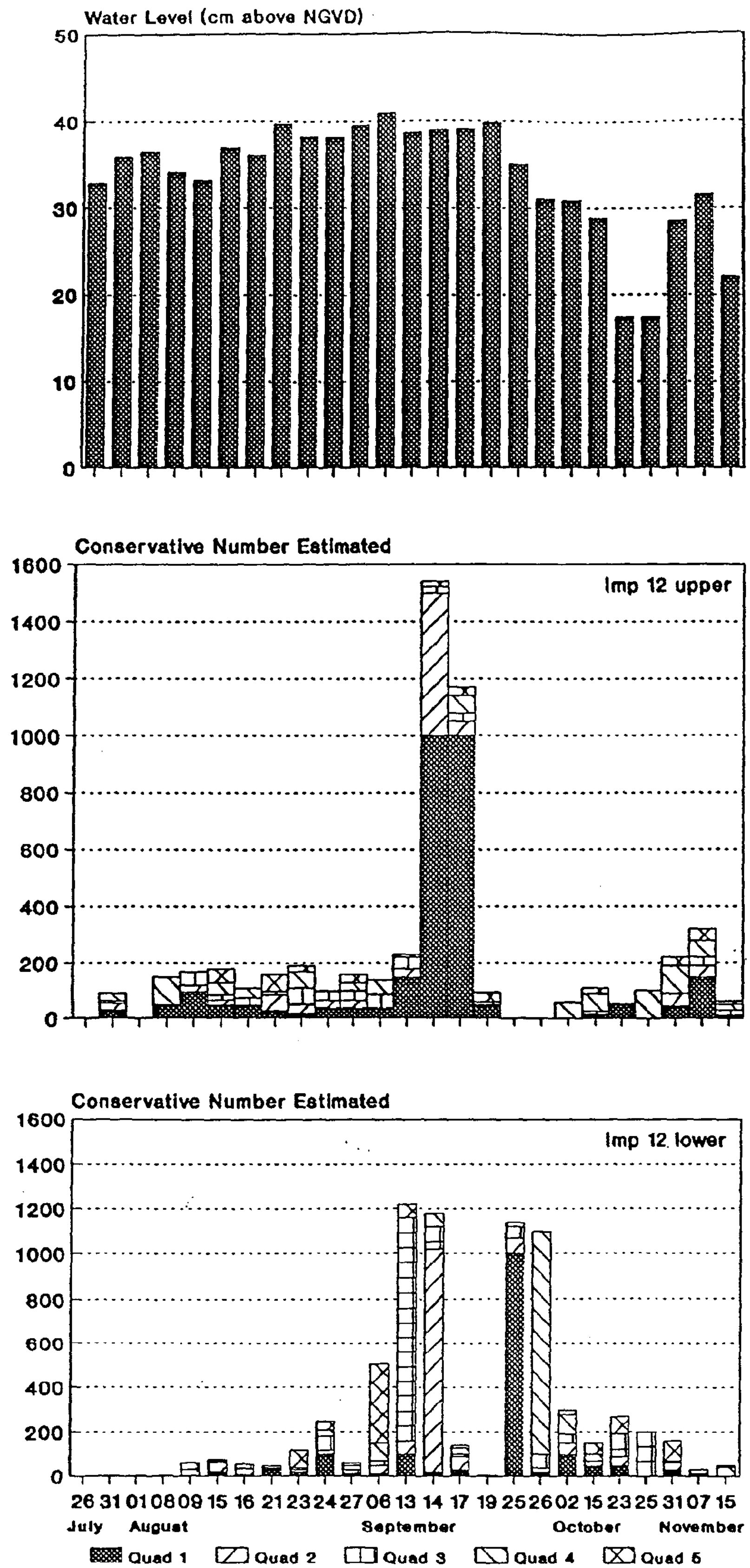
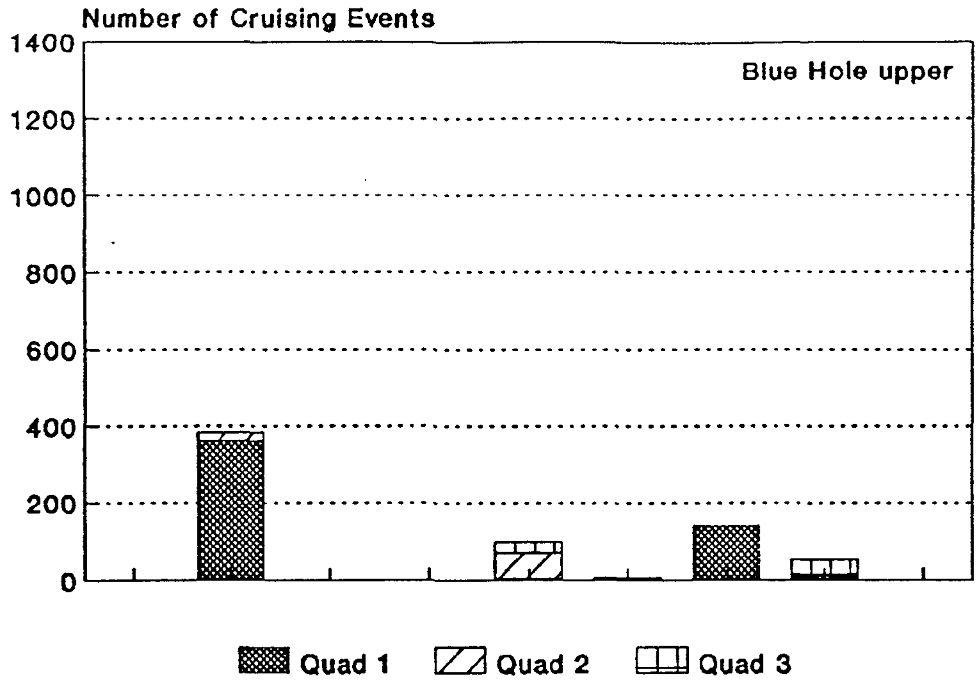


FIGURE 11. Minimal estimate of Cyprinodon densities, in the lower and upper transects of Impoundment 12, based on largest group within the station for each observational period.



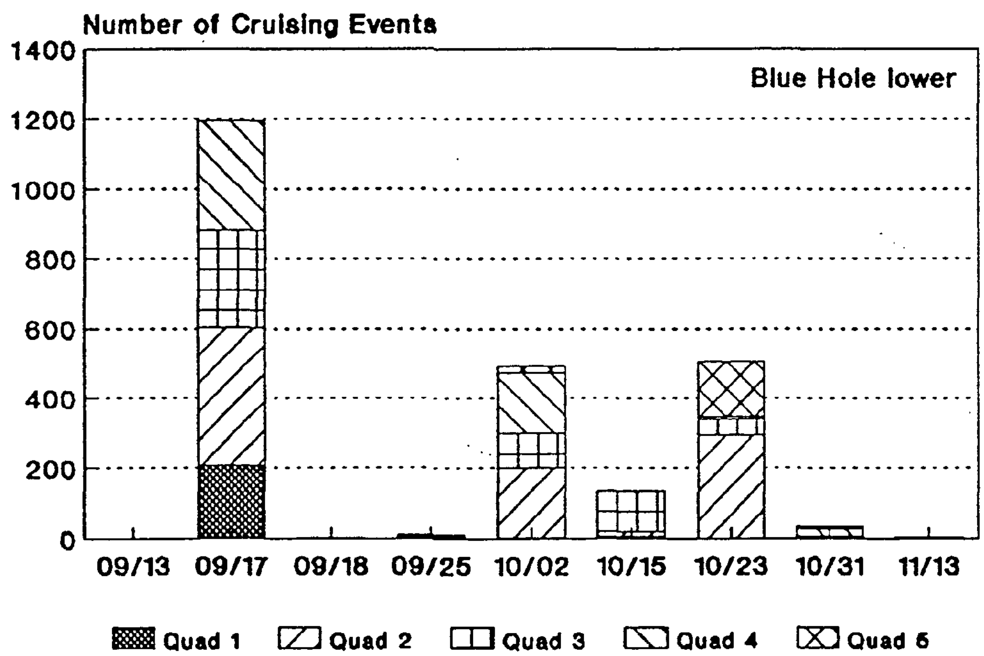


FIGURE 12. Total number of individual Cyprinodon cruising events in the lower and upper transects of Blue Hole Point.

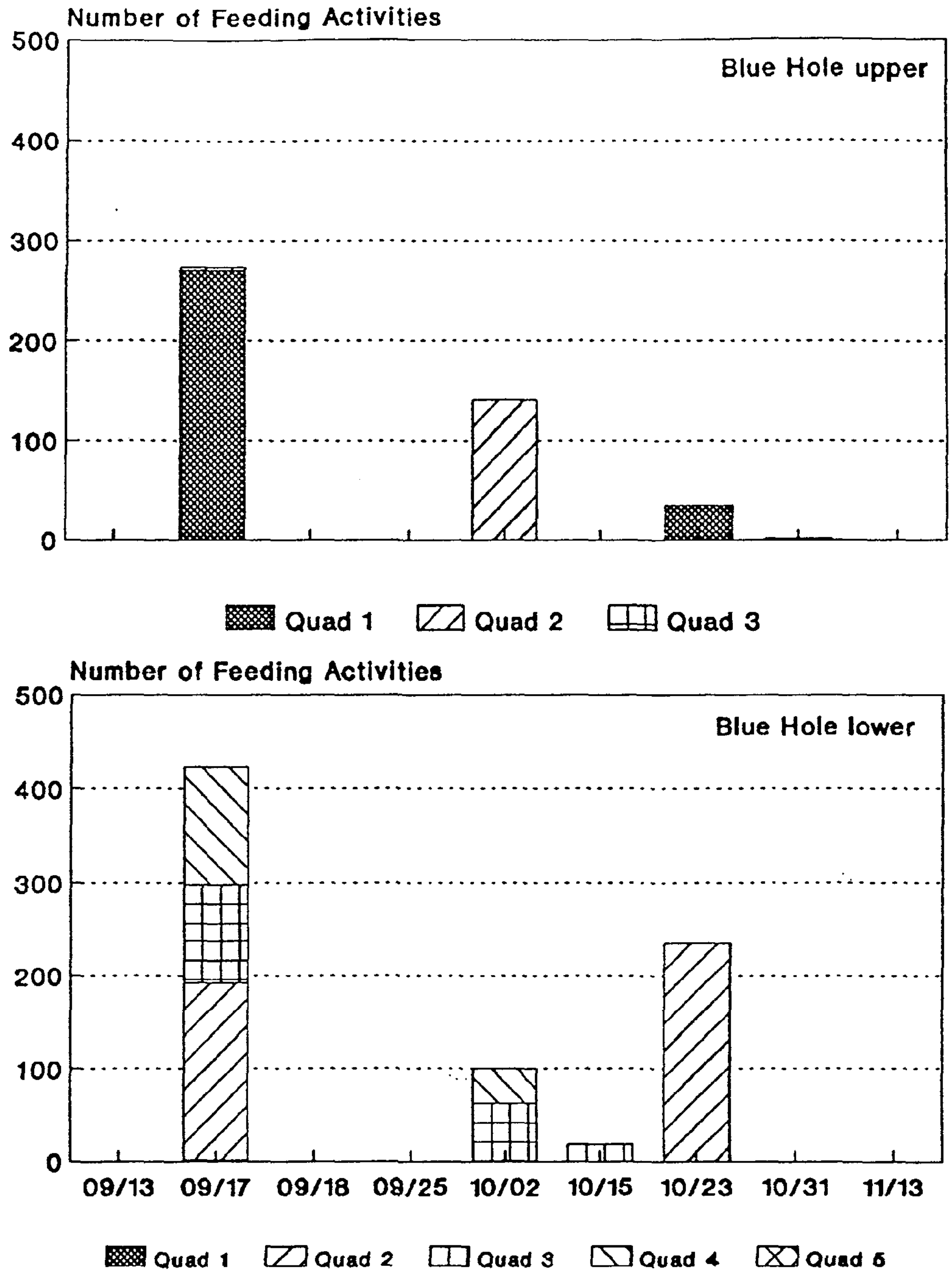


FIGURE 13. Total number of individual Cyprinodon feeding activities in the lower and upper transects of Blue Hole Point.

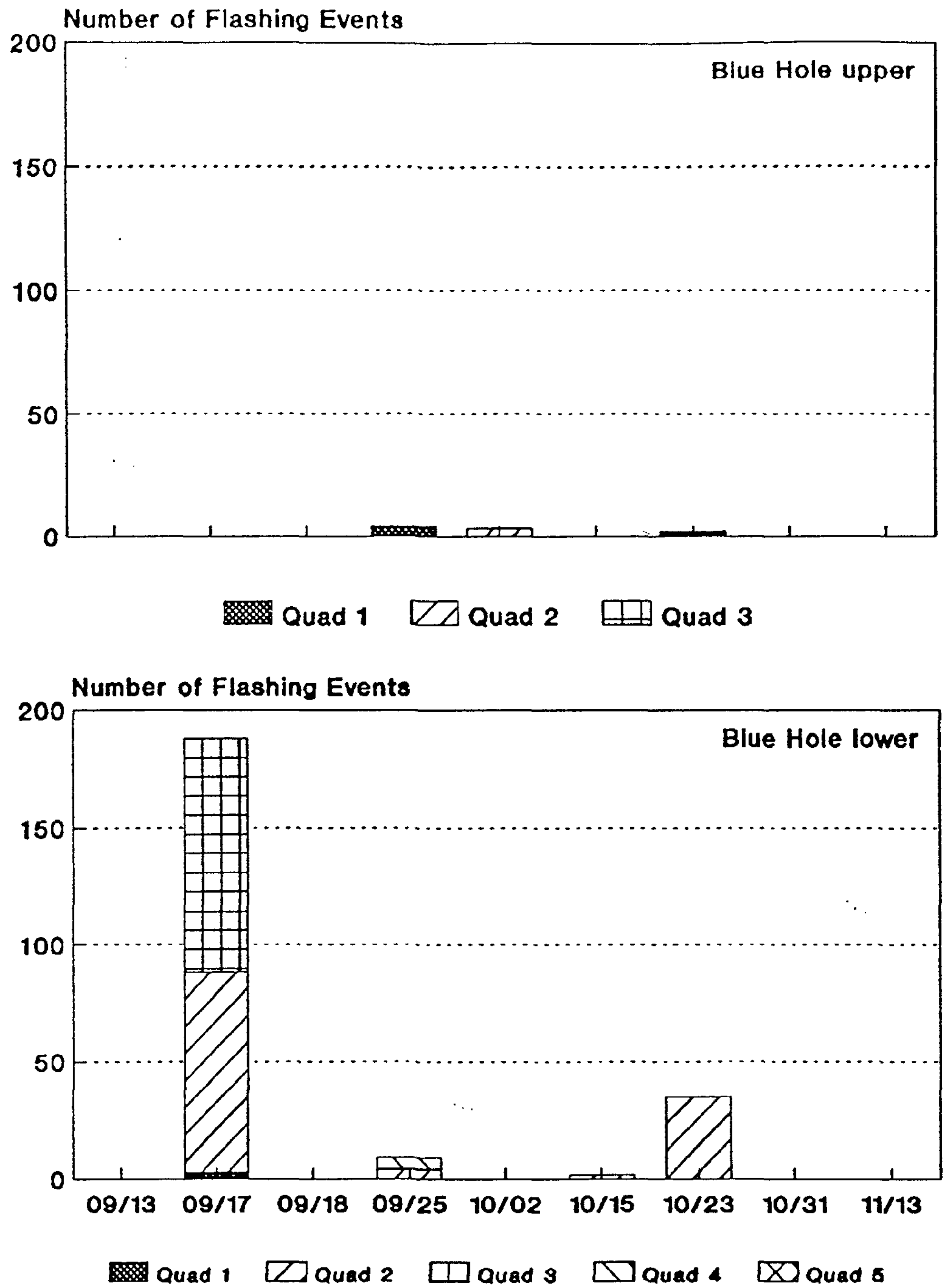


FIGURE 14. Total number of Cyprinodon flashing events in the lower and upper transects of Blue Hole Point.

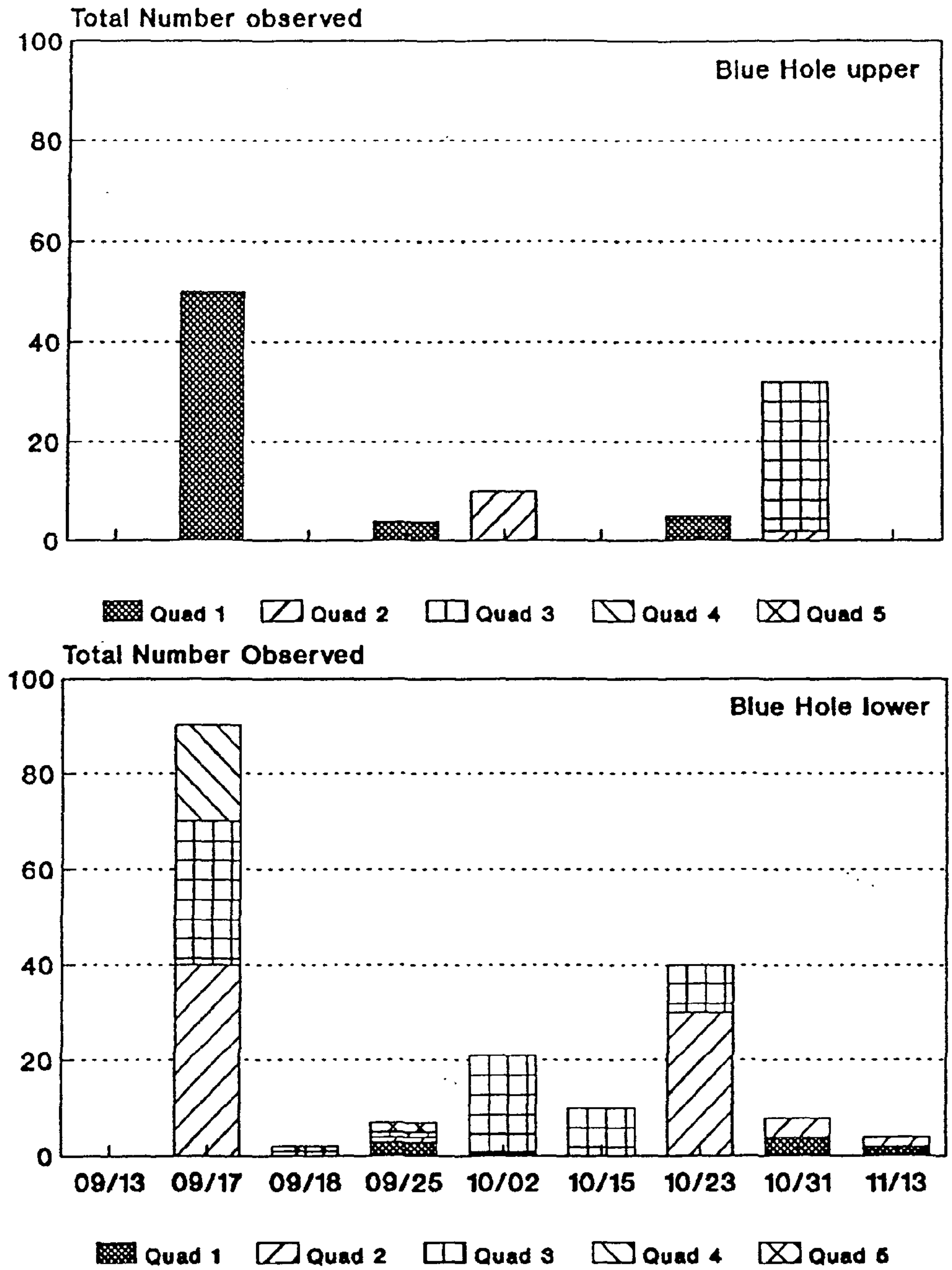
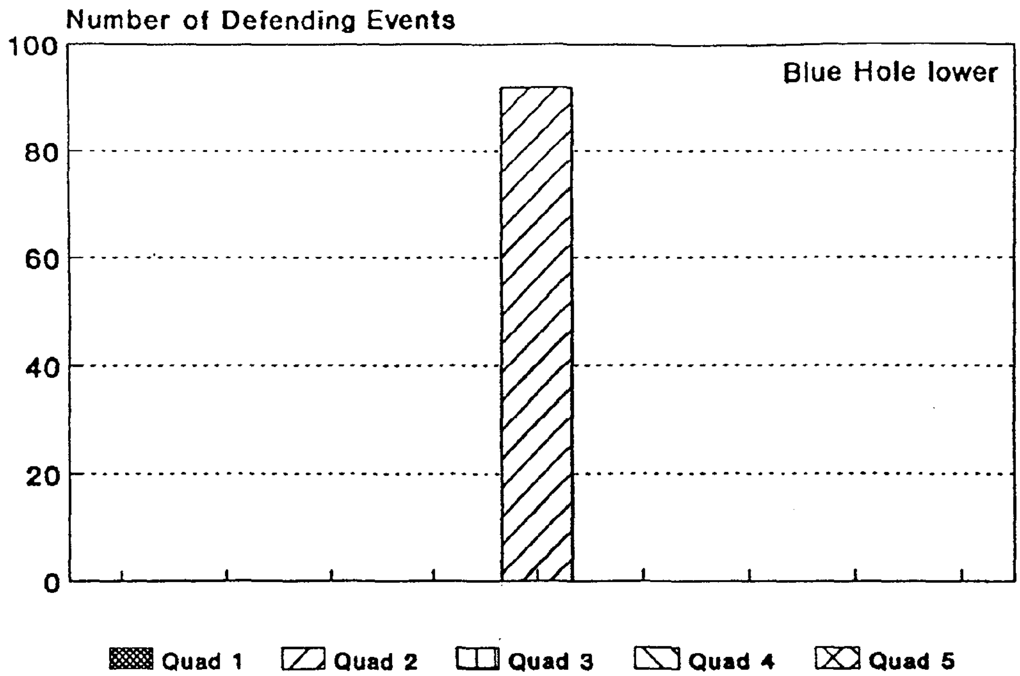


FIGURE 15. Total number of Cyprinodon in the lower and upper transects of Blue Hole Point.



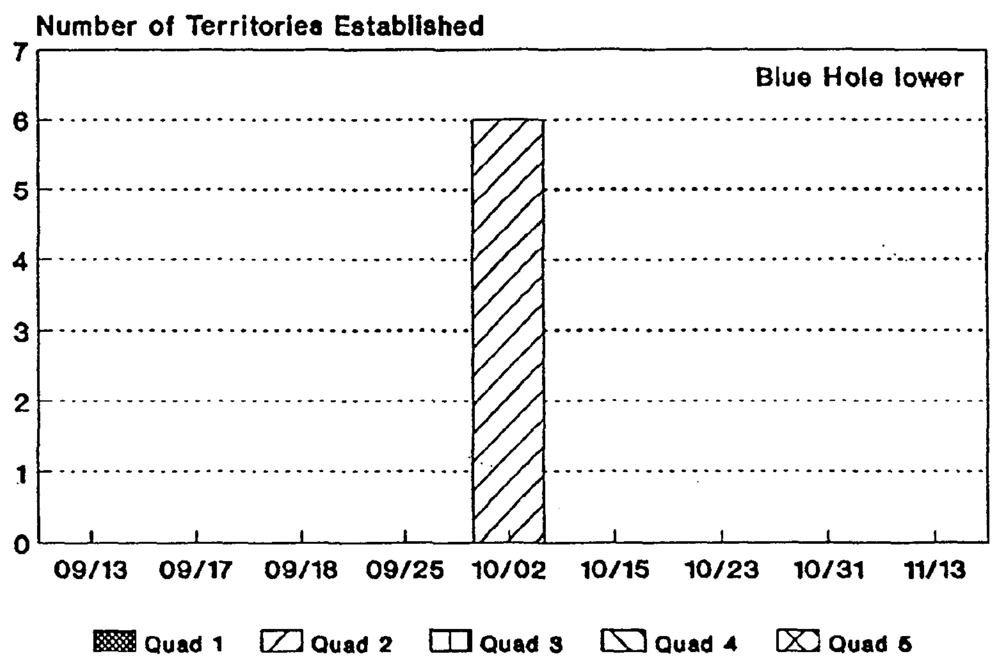


FIGURE 16. Total number of observed Cyprinodon territories and defending events in the lower transect of Blue Hole Point.

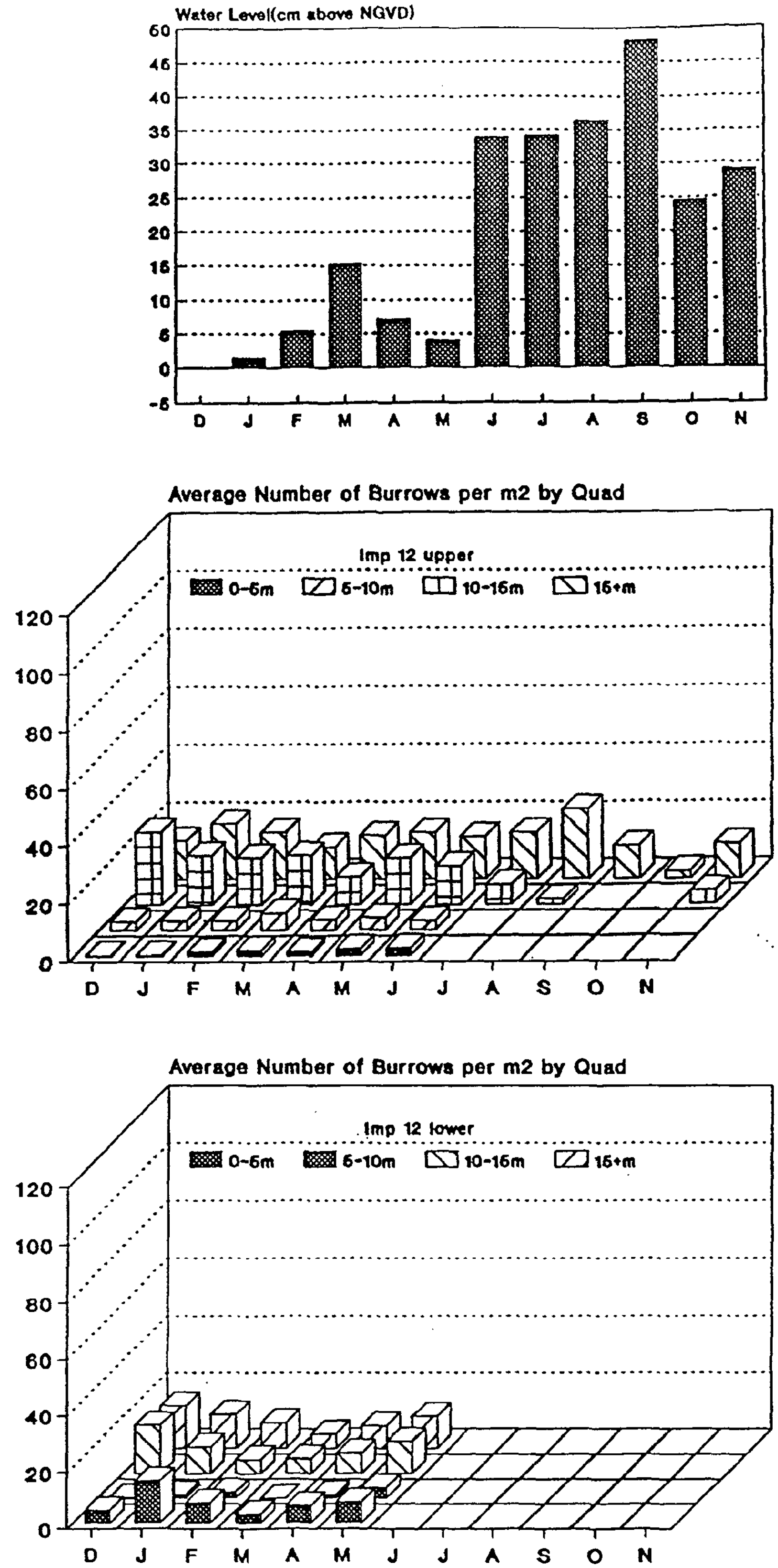


FIGURE 17. Average number of Uca burrows per m^2 for each quadrat by date at Impoundment 12 with mean daily water level.

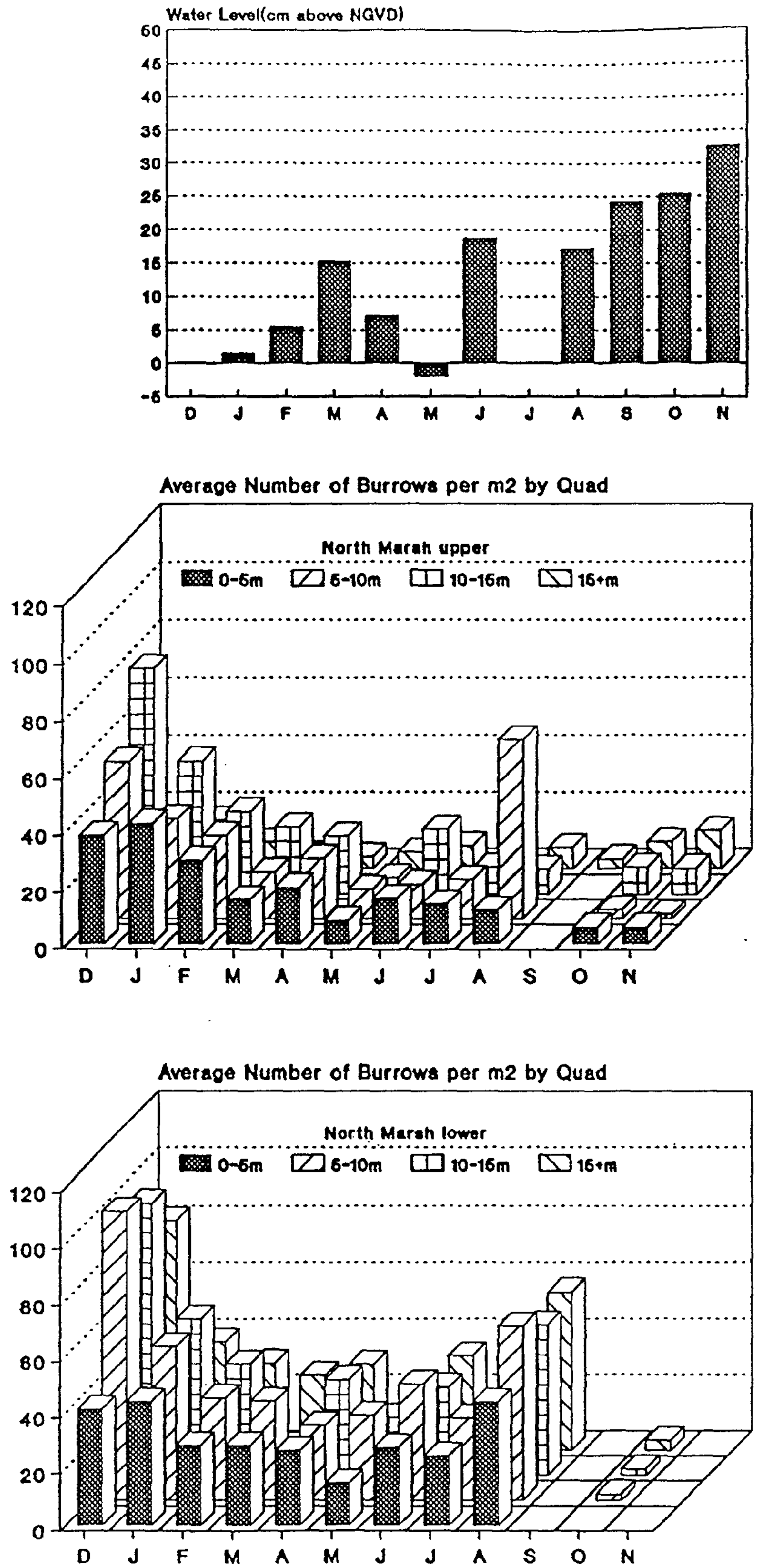


FIGURE 18. Average number of <u>Uca</u> burrows per m^2 for each quadrat by date at North Marsh with mean daily water level.

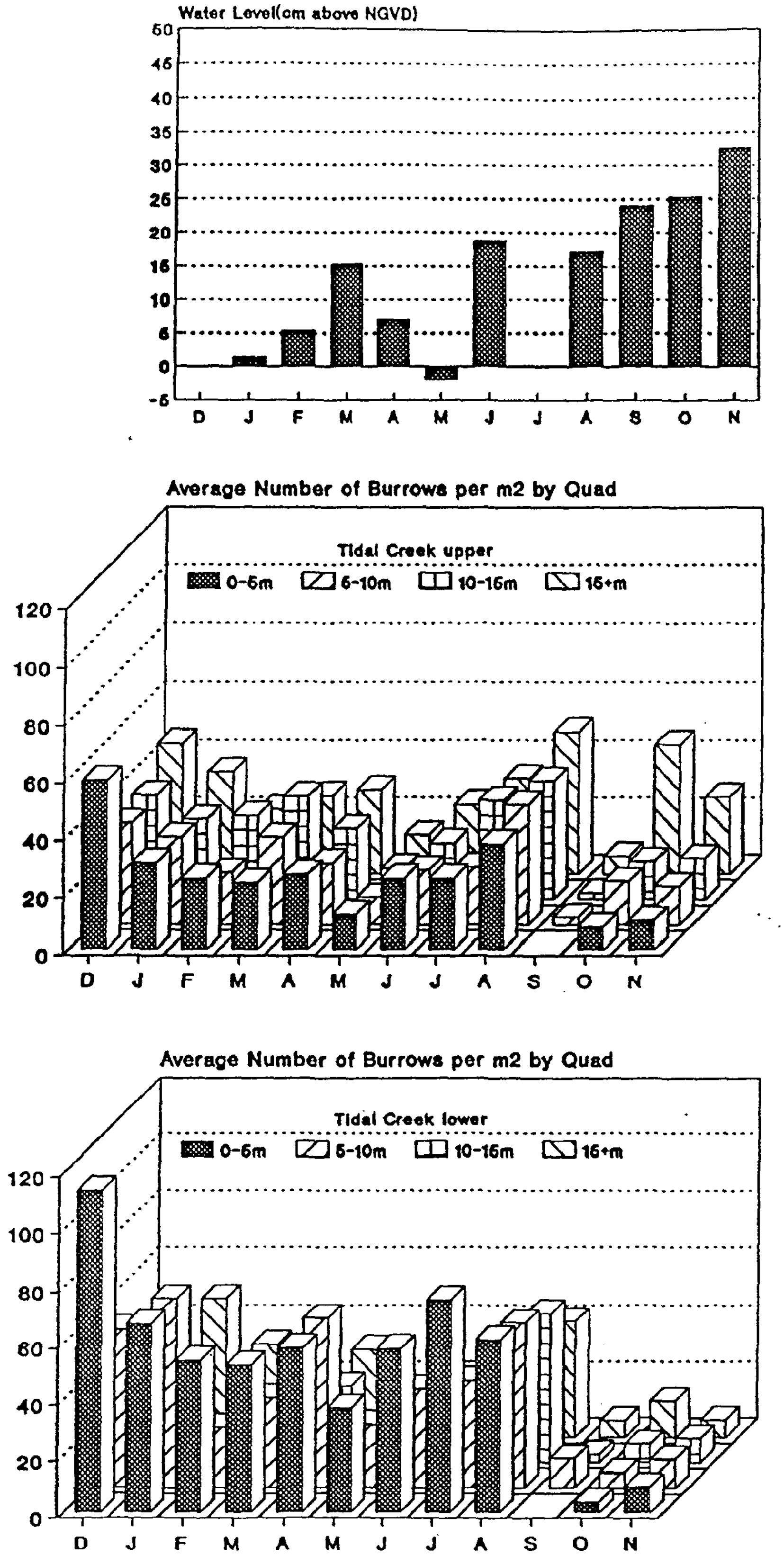


FIGURE 19. Average number of Uca burrows per m^2 for each quadrat by date at Tidal Creek with mean daily water level.

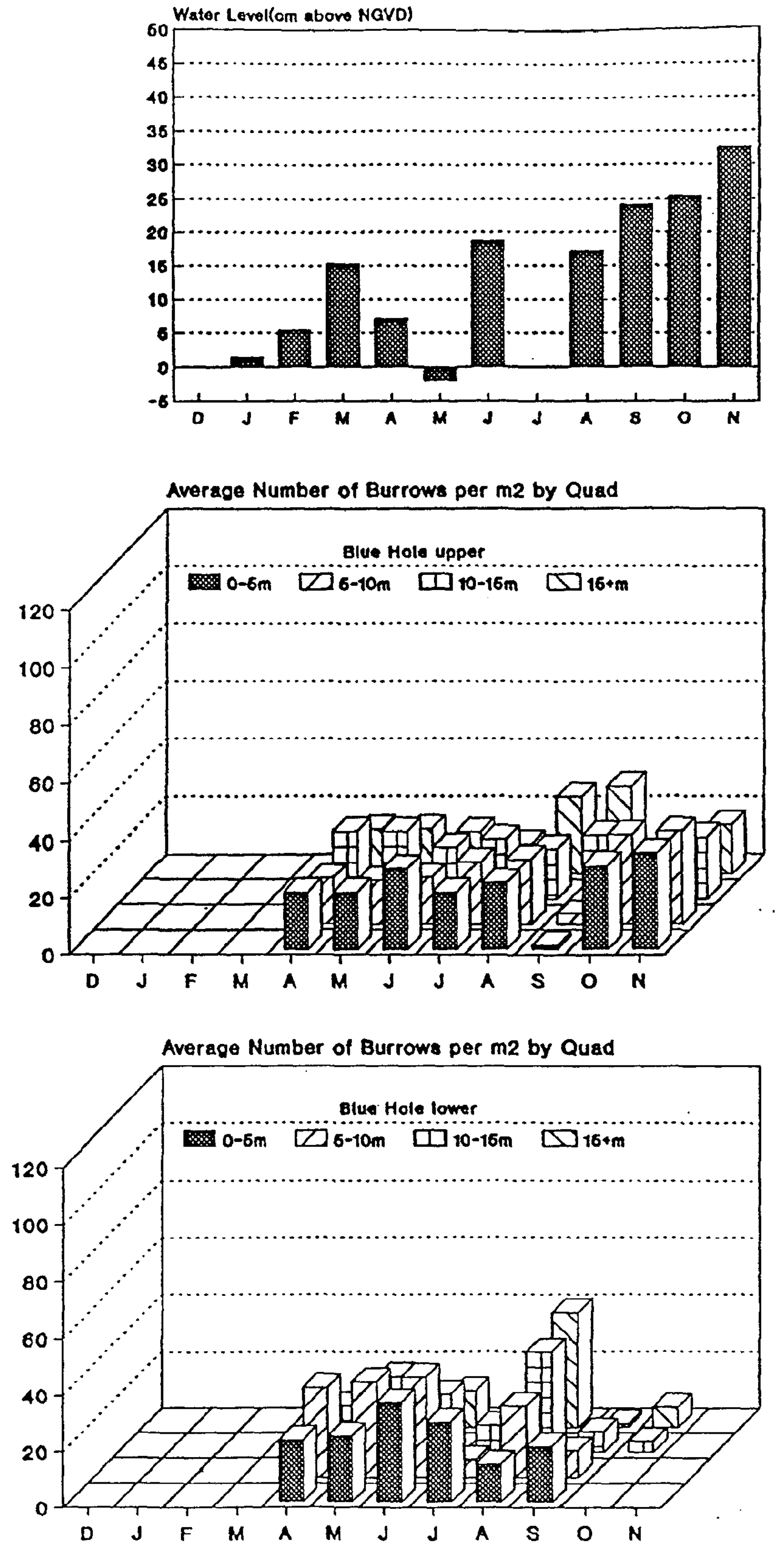
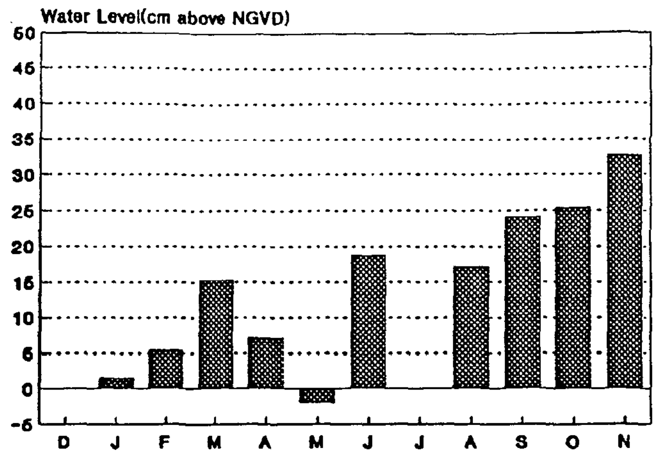
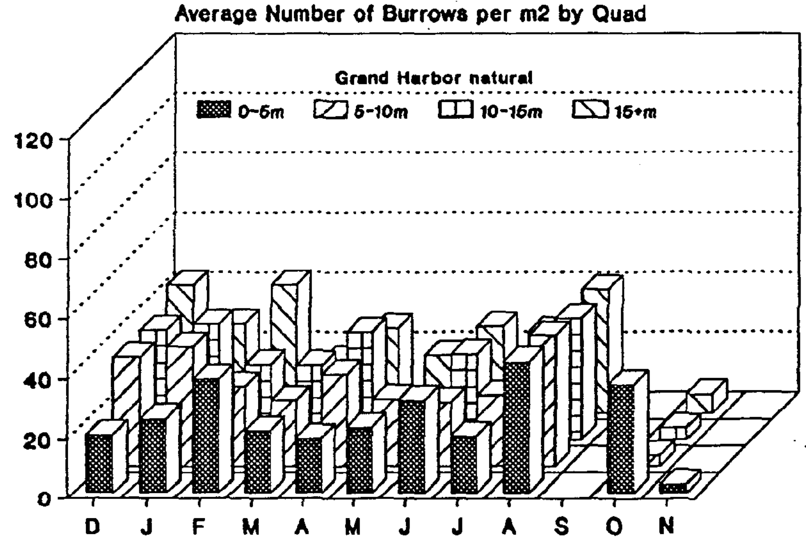


FIGURE 20. Average number of Uca burrows per m^2 for each quadrat by date at Blue Hole Point with mean daily water level.



Average Number of Burrows per m2 by Quad



Average Number of Burrows per m2 by Quad

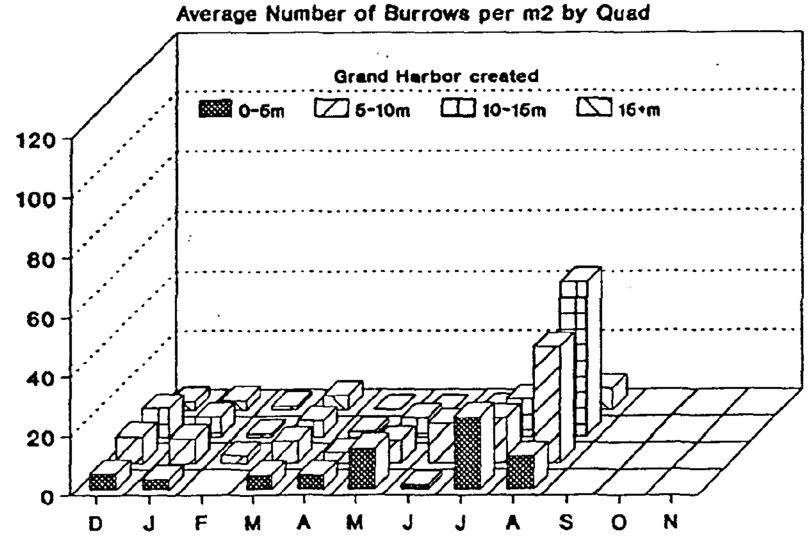


FIGURE 21. Average number of <u>Uca</u> burrows per m^2 for each quadrat by date at Grand Harbor with mean daily water level.